*Anon

The Work of Nature and of Man.

POPULAR STUDIES IN SCIENCE

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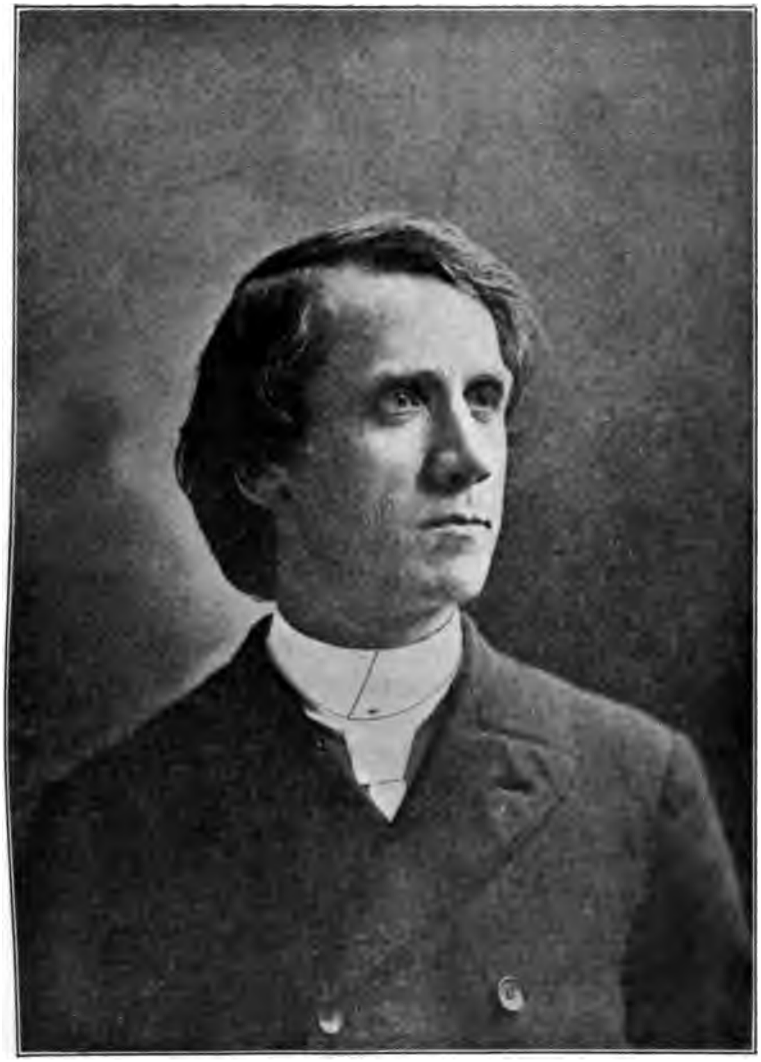

PROFESSOR SEYMOUR EATON

"Segnius irritant animum demissa per aures, quam quæ sunt oculis subjecta fidelibus."

"Things seen by the trustworthy eye, more deeply impress the mind than those which are merely heard."

American College Course

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PROFESSOR SEYMOUR EATON
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Oriole's Nest in an Apple-tree.

From a photograph by A. R. Dugmore.

INTRODUCTORY NOTE.

The world beneath us, the world about us, the world above us—this is the general subject of the lessons in the present volume. How interesting the subject is, the lessons themselves will prove.

Many people suppose that it is necessary to attend college in order to obtain a knowledge of science. This is a very erroneous notion. Some of the foremost men of science the world has known were never at college. The same thing is true of hundreds and thousands of other people who have had great love for scientific study.

For successful scientific study the first requisite is a heart in sympathy with Nature; the next is an observing mind; the next is a determination to make the most of one's own opportunities, whatever these may be.

The lessons in this volume are intended for people whose opportunities for scientific study are only such as lie open to every one. To every one the great world of out-door life is a freely accessible book. With that book, and with such practical help as these lessons will afford, very considerable progress in scientific study can be accomplished.

But of course the greatest gain will be from the suggestiveness of the lessons and the enthusiasm for the study of science which they will inspire.

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THE COLLEGE OF THE CITY OF NEW YORK

VACATION STUDIES
FOR YOUNG NATURALISTS.

VACATION STUDIES FOR YOUNG NATURALISTS.

I. THE SONGS AND HABITS OF OUR WILD BIRDS.

By F. Schuyler Mathews.

In these late days, when considerable interest is awakened in the simpler phases of art and science, natural history comes in for a large share of attention. That is a good thing; we are glad to learn a little more about the wild life of our native woods and fields, and the natural-history books written by foreigners may remain on the book-shelves, so long as we may acquire any small bits of knowledge gleaned from summer saunterings in our new country.

Undoubtedly the rarest thing which attracts our notice as we follow the path through field or forest is the note of a wild bird. Trees are plenty enough, wild flowers are not scarce, and the ferns are all summer long at our feet. But it is now or never with the wild bird's song; it rivets our attention, and we must catch it and know it at once, or else risk the chance of never hearing it again

for a year or more. Birds do not come at one's calling, nor do they sing to gratify our sense of the æsthetic. We must simply be ready for the little singers at a moment's notice, and catch what we can of colour or music; more than that we cannot expect to do.

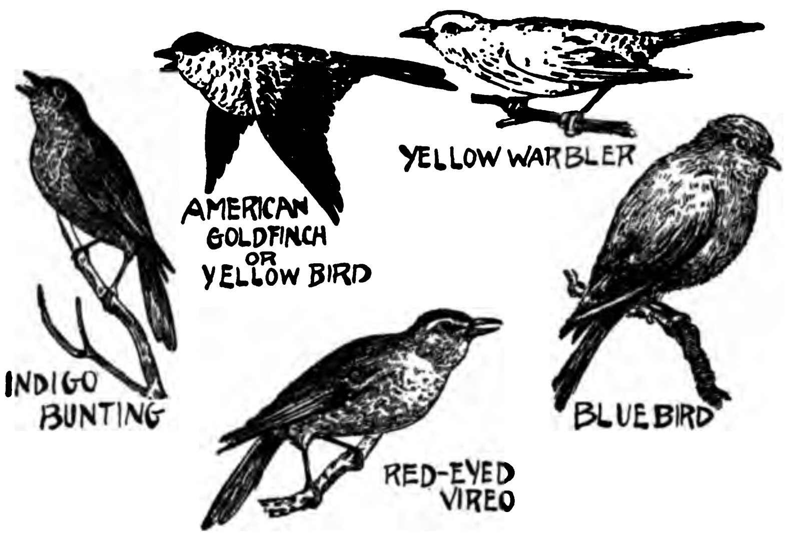
Now for a few hints of preparation. An opera-glass in hand and already focussed is an essential part of the equipment. A position, if we can get it, between the sun and the bird is almost necessary if we would see his colour distinctly; we should note the direction of the tree shadows and endeavour to keep them pointed toward the bird. Next, we must not rustle a leaf, nor make a sudden movement; a bungling, bustling, loud-talking observer will start more birds on the wing than a crazy setter would. Lastly, an infinite amount of patience and a generous allowance of early morning time will, in the end, prove the best means of success.

Again, without a fair knowledge of written music, one cannot expect to be helpfully guided by any one who properly attempts to describe bird music. I cannot wholly rely upon this, that, and the other thing that some writer has said about bird-notes, when he or she does not write those notes down just as a musician would. Some one says the ovenbird seems to repeat the word "teacher, teacher," etc. That is all very well, but it is not enough. I shall presently use some other method of describing the note of this bird. It is also said that the red-winged blackbird sings a sort of "kong-quer-reee"—which again is true, perhaps, but I think we can come nearer the truth with the help of musical signs. It is just to say, however, that these two birds are not musical in the truest sense

of the word; but we should remember that our other songsters with more melodious voices are more easily and truly accredited with the distinct tones and intervals which characterise conventional music.

It seems a most unfortunate circumstance that the scientist is generally a man without the gift of music; to state the case more specifically, the average ornithologist is in a great measure tone-deaf! That may seem to be a rather harsh way of putting it, but I may as well state the fact and deal with it accordingly. If the ornithologist gave us the bird-notes, however lamely, in musical characters, I might think differently; but as he does not even attempt such a thing, it is reasonable to infer that he is a stranger to music. The fact is, the length and breadth of a bird's skull concern him much more than the bird's song. But in our case the conditions are reversed; the song interests us more than the skull.

We look in vain, therefore, for any adequate record of wild-bird music in the best books on American ornithology. To know more about this music it is consequently necessary for us to pursue investigations on our own account. That is not a very simple thing to do, but it is far from an impossible one. The very character and habits of a bird in a great measure influence the structure of its song. The indigo bunting, the yellow warbler, and the American goldfinch or yellowbird sing in the open. The brilliant whistling thrushes sing in the woods. It could not be otherwise, for the songs of woodland birds would sound harsh and shrill in the open fields, and the songs of the other little birds could not be heard in the woods at all at any considerable distance.



A Group of Wild Birds.

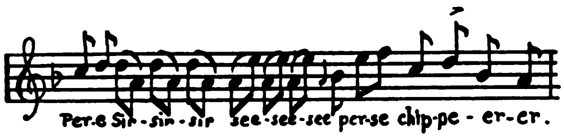
If I should attempt a classification of birds founded upon the character of their music, the order would not differ very greatly from that existing in the ornithologist's classification. Related birds sing similarly—that is all. But, without troubling ourselves about so humdrum a thing as a list of related birds, let us proceed to listen to the music of the wild musicians, with an ear trained to detect the contrasts and similarities of the notes.

Our bluebird (*Sialia sialis*), with a back as blue as the sky and a breast the colour of the red roads of northern New Jersey, has a note the quality of which is metallic, and exactly like the tone of a cut-glass tumbler if it is struck on the edge with a lead-pencil. Exactly the same tone is in the note of the yellowbird. But the bluebird sings in a series of triple notes, and in the minor key, thus:

He is ever in the open, and prefers the orchard or the garden to the dimness of the forest aisles. His gentle, winsome call can easily be distinguished from the noisy,

whistling calls of larger birds. It is his habit to be domestic, and his mate, a far less brilliantly coloured bird, is not averse to a well-appointed bird-house in the near vicinity of the farmyard, where grain and seeds are found scattered about in early spring.

The tone of the voice of the American goldfinch or yellowbird (*Spinus tristis*) is very similar. But the song is altogether different, and is closely connected, like that of a canary. Here is the general character of it; and notice the four final notes especially:



These four notes are exclusively the property of the yellowbird; no other bird sings them, or attempts to sing on the wing just as the yellowbird does. He skims along the sky about five in the evening, and at each dip sings joyfully these four notes, thus:

This so-called American goldfinch is as yellow as a buttercup, all except wings, crown, and tail, which are black as jet. The female is rather of an olive tone tinged with yellow.

A similar-appearing little songster, which might easily be mistaken for a canary, and which is often thought to be one, is the charming yellow warbler (*Dendroica æstiva*). But his character is wholly different from that of the canary, which is a finch and nearer related to our yellowbird. The bills of the three birds show the difference at

a glance; that of the yellow warbler is slender and pointed; those of the canary and yellowbird are abruptly curved, like the sparrow's bill. The little yellow warbler has a bill fitted for light labour, which means that he generally occupies himself with a hunt for insects among the buds and leaves of the shrubbery. He can hardly be called a tree bird, because of his preference for low trees and shrubs; I should never look for him on the top of a tall wild cherry, where the indigo bunting is sure to sing, and if I found him in an apple tree in the orchard I should be sure that he had reached the height of his ambition in regard to trees. So tiny a bird, and one so constantly flitting about in the green-yellow foliage of early May, is not easily seen. But with the opera-glass one may get a fine chance to examine his colours with advantage; the breast is streaked with light brownish lines, and at times his crown appears as yellow as a dandelion. But on the whole his colour is a soft-toned yellow, not far away from the delicate budding leaves he flits among. His song is thin and lisping, very similar indeed to that of the indigo bunting, but shorter and perhaps weaker. I have noticed that it is usually of not more than seven or eight syllables rapidly strung together, and I have imagined that he said something like this: "Yel-yel-yel-ler's the colour 'f me!" But what he really did say was this:

One cannot imitate his voice with a whistle; it must be lisped between the teeth much as a very young chicken chirps. Many birds sing in the two highest octaves on the piano, but this one and the indigo bunting go an octave higher than the piano.

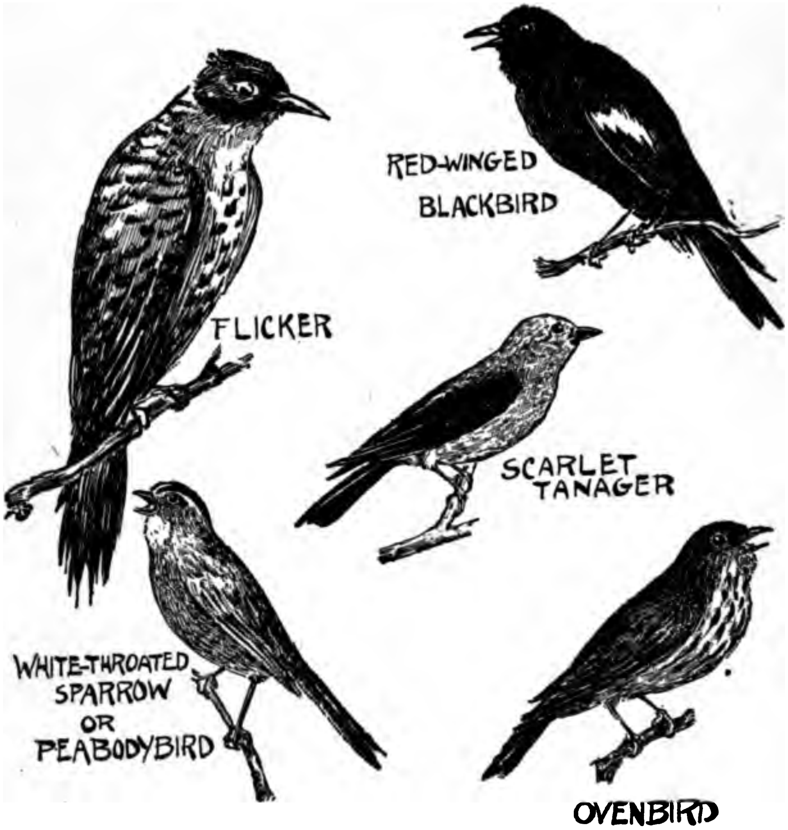
Now, a very near relative of this yellow warbler, but a bird quite unlike him in both habit and song, is the lively red-eyed vireo (*Vireo olivaceus*). This bird is also slender-billed, and classed with what are generally called the "soft bills"; *i.e.*, they are not horny-billed birds, which are accustomed to peck in the ground for grubs and worms. This vireo has a distinctly red eye, with a white and slate-coloured double line over it, and an olive-gray back. He is particularly a tree bird, and delights in hopping through the branches as he sings his happy, disconnected staccato song, which is not lisped, but is sharply and rapidly whistled in a high key. Two, three, or perhaps four notes, are all he utters at a time, and these are delivered at intervals of a second or less—I should say, generally, less. Here is his song as I got it this May in the Arnold Arboretum, near Boston:

The red-eyed vireo sings all summer long—that is, up to the middle of August usually—and his notes are familiar to me in the depths of the deciduous forests of the White Mountains and the Catskills. Another singer through July and the early part of August is the indefatigable little indigo bunting (*Passerina cyanea*), a bird as

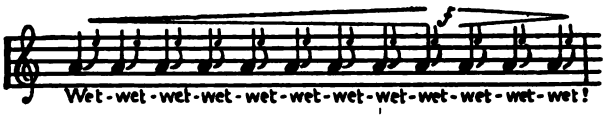
blue as his name indicates, and as canary-like in his song as the yellowbird. It might be an easy matter to confuse the song of this little bunting with that of the yellow warbler, but a diligent comparison of the music of the two birds reveals this unmistakable character in the song of the bunting—his introductory notes are invariably distinctly slurred and deliberate. The rest of his song is like that of the yellow warbler, and it is also of a lisping quality, thus:

When he sings he generally occupies the topmost twig of a roadside tree, where he can view the surrounding country and keep the track of the other birds, whom, it is to be presumed, he intends to impress with the extraordinary power of his voice!

But for power and emphasis, without so trivial a thing as melody, we must listen to the soul-inspiring notes of the yellow-hammer, or golden-winged woodpecker, or flicker (*Colaptes auratus*), a long-bodied, gay bird with a gray top-knot, a bright scarlet band over the back of his neck, and more common names than there are spots on his breast—which is saying a great deal! The flicker is, indeed, a character; besides his names, such as yerrup piut, hittock, Harry Wicket, wake-up, yucker, woodwall high-hole, etc., he has powers of vocalisation which, however limited in scope, are certainly not limited in quantity. He will let off a series of notes like this—



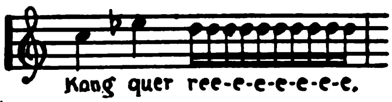
A Group of Wild Birds.



until the air is so full of them that there appears to be no more room left for any other bird music. However, he does not frighten his bird neighbours, as they appear to sing on unconcerned with so unmusical an interruption. But it is certain that while the flicker does sing there is no hearing anything else. If I may call the ovenbird (*Seiurus auricapillus*) a less noisy creature I certainly cannot consider him more musical. He is an olive-brown bird with a somewhat yellowish crown and a gray-white breast brown-streaked. His note resembles the whistling-swish of a whip being lashed back and forth through the air. Burroughs thinks he says "teacher, teacher, TEACHER, TEACHER," which is a very good interpretation of the song. But I will render the notes in music, which I think is more intelligible:

Then there is another unmusical bird whose note is commonly interpreted as "kong-quer-ree-e-e." This is the red-winged blackbird (*Agelæus phœniceus*), a haunter of reedy ponds boggy places, and wet meadows. He is glossy black, all but his shoulders, which are decorated with scarlet epaulets. It is a pity to call him unmusical, though, for he is not at all noisy, and even if his note has

no decided pitch nor clear whistle, it is not without some musical cadence. Indeed, a particularly soft singer which I heard this spring distinctly suggested a musical third. Here are the notes:



If we understand the essential principle of music we shall be ready to allow a broad margin for what may properly be termed musical suggestiveness. A bird sings and suggests a melody to one person and nothing whatever to another. For the one who hears no melody it simply means that he was unprepared to allow his imagination to trace or follow the "trend" of bird music. If I detect in the blackbird's notes a tendency toward a clear musical third, I count it as a fact that he sings a third; anyway, I am sure he tried his best to do so.

If we listen for something we are the more likely to hear it. A musical third is one of the simplest of all musical forms. It is the musical measurement between C and E in the natural key; a musical fifth would be the measurement between C and G. Now, we cannot expect birds to make any such accurate measurements of tones; that was left for a man to do on the keyboard of a piano. But it is very plain that birds very often do sing correct thirds and fifths and even octaves; so when we find some little individual bird-mind striving unsuccessfully to express itself in correct musical form, it is reasonable to credit the creature with the attempt.

It is impossible for me to describe or imitate the red-winged blackbird's note; it has a charm like the Pied Piper's flute—it draws, but the reason why is not plain. The syllable "ree-e-e" resembles the "sing" of a small buzz-saw, but the buzz-saw of some fairy factory, where they make the wooden pipes for the bullfrog's orchestra!

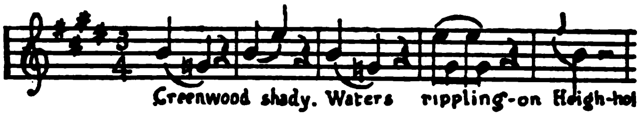
There is a little bird, however, who does successfully strike a third or a fifth or even an octave without the shadow of a doubt. This is the white-throated sparrow, sometimes called the Peabody bird (*Zonotrichia albicollis*), a true woodland bird, which has a clear whistle and a perfect ear for tone and pitch. Once in a while some less gifted individual falls away in flats, and slides down the scale in a comical attempt to do something beyond his ability, but as a rule all the others sing in well-marked time and perfect pitch, trembling on the last triple notes as if lacking assurance. Here are exactly the tones of an accurate singer which I have recently heard:

The white-throated sparrow is distinguished by the broad band of white under his chin, the white stripe over each eye, and the rufous brown on his back, streaked with black. His favourite home is among the foothills of the White Mountains and also in Tuckerman's Ravine, directly under the southern slope of Mount Washington.

Of all the birds of the northern woods, the most brilliant one is the scarlet tanager (*Pyranga erythromelas*). His

magnificent colour when once seen is never forgotten; it is like the revelation of a new bird of paradise. His coat is a magnificent scarlet, with wings and tail of a glossy black. The female is in wide contrast with her mate, and the robe of æsthetic yellow olive which she wears only sets off her resplendent husband's scarlet raiment to a greater advantage, and one forgets that she is a pretty bird herself. The scarlet tanager's home is in the depths of the forest shade, but he also frequents the scattered trees by the roadside. One may often see him in the deep woods, it is true, but his colour there is not so easily displayed, and as a consequence it does not readily catch the eye. But let the beautiful bird fly across the road and alight in a sunlit maple and the gorgeousness of his feathers is apparent at a glance. He is, in fact, a flash of vivid colour, as startling as unexpected amid the sober green of the woodland.

And his song is as beautiful as his coat. It is like that of the robin in construction, but entirely unlike that of any other woodland singer. The notes are not clearly whistled, nor are they thrilled or warbled; they are the scarlet tanager's own, and that is all I can say. To imitate them I must hum and whistle at the same time. His notes are almost invariably grouped in twos; rarely there are three notes connected together, and often there occurs a note that sounds like a trill, but which upon careful analysis proves to be rather a rapid interchange between two notes, perhaps a fifth apart. Here are two songs recently heard in the Arnold Arboretum, close by but not wholly in the sombre shades of the hemlock hill beside the eastern gateway.



The greatest charm of the scarlet tanager's song is its soft quality. It is vigorous yet not loudly whistled as the oriole's song is. It is like the robin's song, but there is not an atom of that nervous quickness which characterises the robin's music. The scarlet tanager's song is well worth taking a long tramp to hear. And when it is once heard, I am sure the memory of it will abide always. It is one more thing to be added to the list of which the heading naturally is

> "A thing of beauty is a joy forever."

BOSTON, MASS.

II. THE BUILDING OF A BIRD'S NEST.

BY CHARLES C. ABBOTT, M.D.

WHY birds build nests seems strange when we consider that everywhere there are abundant nooks and crannies that might be utilised and which would prove quite as safe as the frail structures many birds do build in trees and bushes. The origin of nest-building opens up too wide a field of discussion to be treated here. It is enough to know that most birds build nests and a great many do not, and that the nests of different species of birds vary greatly. There are nests which are mere platforms of sticks that do not hold together until the young birds are able to take care of themselves, and from such simple structures we find a gradually increasing skill in nest-building to the woven fabric that will withstand the storms of more than one season.

There are four familiar birds that can be observed very readily and without wandering far afield. These are the chipping sparrow, the robin, the oriole, and the barn swallow. The "chippy" is almost a domesticated bird, and very promptly, on settling down for the summer, he selects a nesting site. The selection of material demands judgment, and if we watch closely we shall see the bird

A MOCKING-BIRD.

Photographed from life by A. R. Dugmore.

picking up many a little twig, flexible rootlet, or blade of last year's grass. It is sometimes carried off and then rejected, but more often the bird lifts piece after piece and then tosses it aside with an impatient movement of the head, and you almost fancy that you hear "Pshaw!" In-

WOOD THRUSH'S NEST.

deed, the bird does sometimes chirp in a way that clearly indicates disappointment. But the trouble does not always end in the selection of a bit of material. It may meet with approbation on the part of one and disapproval on the part of the other bird. Though very loving generally, mated birds have been known to quarrel, and more frequently, I think, when their nest is being built than at any other time. Later the more serious demands made upon them give them less time to think. The foundation laid down, the building of the sides is quite rapid, but it is not

a careless pitching together of the material gathered. Piece by piece it is fitted together, so that when the structure is finished it is so firm that no repairs are ever needed. I have known these nests to be blown out of trees in the

BLACKBIRD'S NEST.

winter following their construction, to be rolled over rough ground for a long distance, and yet hold together. For the nest the chippy requires hair, and that of the horse and cow is generally used. There seems to be no loss of time in finding all they need, and here we have an instance of the bird's skill in collecting. Try to find a dozen hairs of horse or cow and see how long it will take. Yet the bird does not pluck the desired hair from the animals, or even enter stables and cow-sheds in search of them. This hair, which is coiled round and round, completes the

building of the chippy's nest. It may have been a matter of three days or a week, but, whether the one or the other, if patiently observed there would have been noted most of the virtues and all the infirmities of mankind. The angelic is only a large fraction of bird nature, and no honest naturalist will overlook the remaining fraction.

As set forth, all this may seem the climax of dulness,

ROBIN'S NEST.

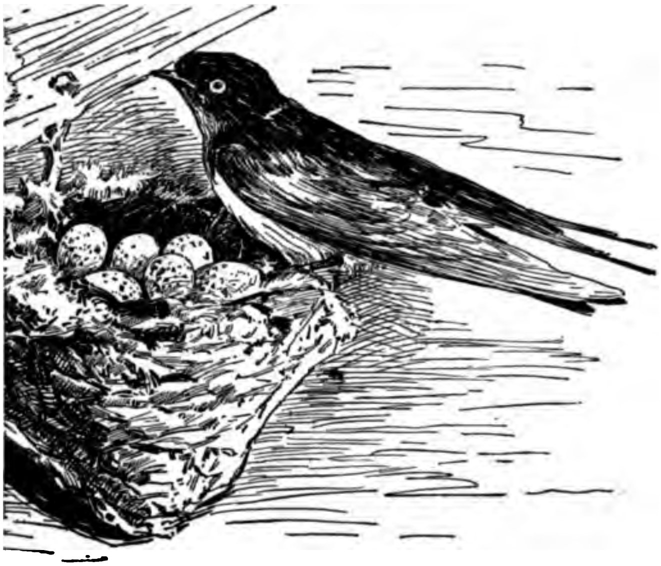
and the young aspirant for natural knowledge will be disappointed in the absence of adventure, but excitement of a healthy kind is really seldom lacking. Never a chippy but has its foibles, and these will show themselves upon occasion. I have waxed coarse black sewing-silk until it looked like hair from a horse's tail, and the deceived bird has had to put on its thinking-cap to some purpose to solve the mystery. You only need, first, patience and ingenuity on your own part to measure the intellectuality of many a little bird. No great naturalist ever became so at a single leap.

The robin is so much larger a bird that fewer difficulties are encountered in observing it from start to finish. Its nest is often in so exposed a position that we wonder it was chosen, and the bird's judgment sometimes proves at fault. A storm, a sudden gust of wind, may render it untenable and it is abandoned. The robin's nest is not merely a large cup-shaped structure built of coarser material than that used by the chippy. It is lined with mud instead of soft material, so the bird in a way is a mason as well as carpenter. Here a problem arises: What advantage has mud over hair and small feathers? It has not been solved, and probably never will be, but it is a wholesome exercise of your imagination to go over all possible reasons, and some day when you least expect it the truth may become plain.

But if sitting hour after hour watching robins at work proves a little tiresome it will not be so when the Baltimore oriole weaves the pendent nest. This bird selects strong, flexible materials, and, selecting the end of some far outreaching branch, ties curious knots and then lets fall long loops of string, which form the framework of the future nest. Then follows the interlacing of shorter threads, and a close-woven fabric is the result. It proves a fairly good water-proof cloth when finished; in reality a bag with an opening at one side, or more frequently at the top. How the bird manages to hold on to slender twigs and with its beak accomplish all it does is marvellous; yet it is not deterred by stiff breezes and appears to enjoy its work the more as difficulties arise, if we may judge from its songs that mark every moment of leisure. To appreciate what the building of such a nest means it

Oriole and Nest

must be examined carefully, but never under any circumstances until the bird is through with it. It is never justifiable to rob a bird.



BARN SWALLOW AND NEST.

Turn now to the nest of a barn swallow, which has been aptly described as "half a teacup stuck against a wall." The foundation is clay and sand, which they work up into mortar, and as tiny pellets carry to the nesting site, usually a rafter in a barn and near the peak of the roof. Bit by bit these "bricks" are placed in position and are glued together with an adhesive salivary secretion. Then come the grass lining and a few soft feathers.

These four nests represent in a way those generally to be found during the summer. There are endless varia-

tions in different directions, and it is the business of the young naturalist to determine their character and ownership. It will prove an interesting exercise to learn what bird has built the nest you have discovered. Let the nest be the means of thorough acquaintance with its builder, and rest assured that to know a bird is to love it, and loving it you will be its staunch defender.

TRENTON, N. J.

III. INSECT CARPENTERS, BUILDERS, AND WEAVERS.

BY ANNA BOTSFORD COMSTOCK, B.A.

THE WATER SPRITE.

ALTHOUGH spiders are the most famous spinners and weavers among animals, yet we have many insects which are also very expert in spinning silk and weaving tapestries. Most of the insect spinners are caterpillars—*i.e.*, the immature forms of butterflies and moths and allied insects. Different species of caterpillars put silk to different uses. Sometimes it is used for shelter, and sometimes for blankets, and sometimes for catching prey, and sometimes it is used as a paving for roads, and almost always it affords a means of descent from high places to the ground. But, unlike the spider, who has his spinnerets arranged on the rear of his body, the caterpillar has his spinning apparatus attached to his lower lip. It would seem that this was a better location for the spinning glands, since the caterpillar can thus better see what he is doing.

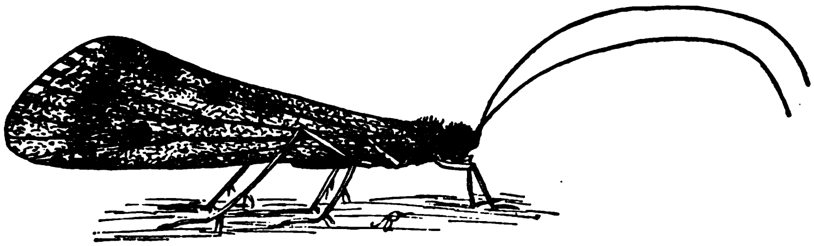
One of the most skilful and interesting of the insect spinners is a little fisherman who lives at the bottom of

INSECT PAPER-MAKERS.

A Hornet's Nest.

From a photograph by A. R. Dugmore.

swift-flowing streams and is common throughout the northern United States. This fisherman belongs to the family of caddice-worms—a family widely celebrated for skilled carpenters and masons. Our fisherman, however, is neither a carpenter nor a mason, but is skilled in the art of making nets. His scientific name is *hydropsyche,* which, translated, means *water sprite.*



WATER SPRITE—THE ADULT MOTH.
(Actual size, about one-half inch.)

His favourite haunt is at the bottom of some stone that lies in a swift current; his dwelling is rather carelessly constructed, and consists of a tube of silk or bits of sticks woven together, which is fastened to the lower surface of his chosen stone. This house, however, is only a place of retreat, and it must not be supposed that this rude silken tent is the true test of the technical skill of the water sprite.

In appearance the young water sprite is a small caterpillar, varying in size according to age and species. Our most common species is about a half-inch in length when fully grown. It is brownish or greenish in colour; his three pairs of legs are long, and his black eyes give him a very alert look. At the rear end of his body are a pair of

strong hooks. He does not need to come to the surface of the water for air, since he has bunches of thread, like gills on the lower side of his body, fitted for extracting the oxygen contained in the swift-flowing water.

The water sprites build various-shaped nets, each species making its own peculiar kind. The one figured here makes a funnel-shaped net, which is fastened to stones so that its distended mouth is directed upstream. The sides consist of a framework of bits of vegetation, fastened together by closely woven silk, but the opening at the small end is covered with a strong, regular, and comparatively large mesh. The supreme skill of the water sprite is shown in the beauty and regularity of this part of the net. The advantages of this arrangement can be seen at a glance, since this large mesh allows the water caught by the wide mouth of the net to flow through easily and thereby leave in the silken bag creatures too large to pass through. The simple mechanism keeps it always in place and always in working order. Near the end of the net and on the side next to the current is an entrance which leads into the roughly constructed tube in which the water sprite lives, so that he may gather the contents of his net without leaving his house.

It is marvellous how this little creature keeps his foothold in such swift currents. Probably the strong hooks at the rear end of his body are used to clutch his silken ropes and thus hold him to his anchorage. The very brink of falls is a favourite location for him, and he hangs his silken cups in this perilous position and there they stay, long after their owner has abandoned them, making the rocks black from the dirt caught in their meshes.

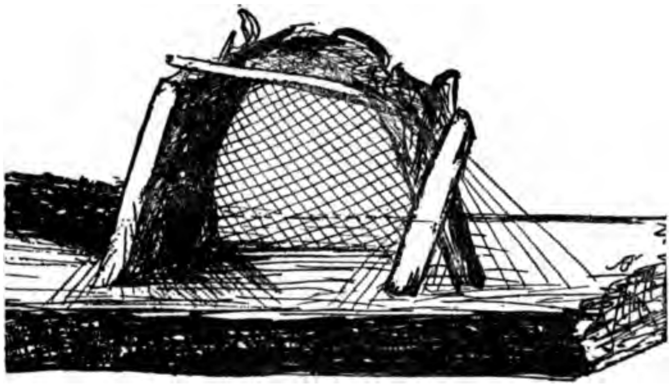
Though the water sprite lives most of his life in the water, yet he attains the sunshine and air as a climax to his interesting career. The pupa stage is passed in a carefully constructed case made of bits of gravel fastened together by silk, with a silk grating at each end to allow the water to pass through. After he bursts the pupa skin he tears away the grating and rises like an arrow through

WATER SPRITE—THE LARVA THAT IS A FISHERMAN.
(Actual size, about one-half inch.)

the current and reaches the surface. As he thus darts upward he swims with his long legs and bears his wings folded compactly upon his back. However, the moment he reaches the surface his wings unfold like magic, and off he flies, a true child of the air. The rise from the bottom of the stream and the expanding of the wings only occupy a few seconds of time. With most insects the expanding of the wings after the pupa stage requires hours. But the water sprite has no time to waste, since if he does not escape from the swiftly flowing water the moment he reaches the surface he is swept away and drowned.

If you should see him now you would find an inconspicuous little brown moth, with his wings folded rooflike over his back. His life in the air is short but very happy. A part of the time he devotes to the wooing of a bride, and the rest he gives to solving the mystery of light. When at night he sees a flame from afar he dashes toward

it with mad enthusiasm, not only toward it but into it, with no fear of the results. The strange fascination that light has for these creatures seems inexplicable, unless it is that through a long life in the element of water their ideals are embodied in the opposing element of fire. Certain it is that at the first opportunity the water sprite



THE NET OF THE WATER SPRITE AND THE ADJOINING TUBE IN WHICH HE LIVES.
(Actual diameter of net, about one-half inch.)

changes to a fire-worshipper. Only in recent years have the many inventions of man interfered with his sacrificial ending. The placing of glass about the street lamps, the invention of electric lights shut away within globes, raise barriers that prevent the ecstatic holocaust.

He and his fellows come in myriads and hang, a living curtain, about the lights of cities situated near rivers. These moving masses of winged creatures, each struggling to get nearer the dear flame, have proved a great nuisance in the cities upon our chain of great lakes. In

Buffalo, when the question of the Exposition site was being discussed for the Fair of 1901, many people, with a view to a beautiful setting for the architecture of the Exposition buildings, voted for a site by the water-side. However, somewhere in the swift current of the Niagara River millions upon millions of water sprites spread their nets, and the committee on sites fear that whoever else may come to the fair these little folk will be sure to be there in crowds that will prove disastrous to the comfort of other folk for whom the fair is intended.

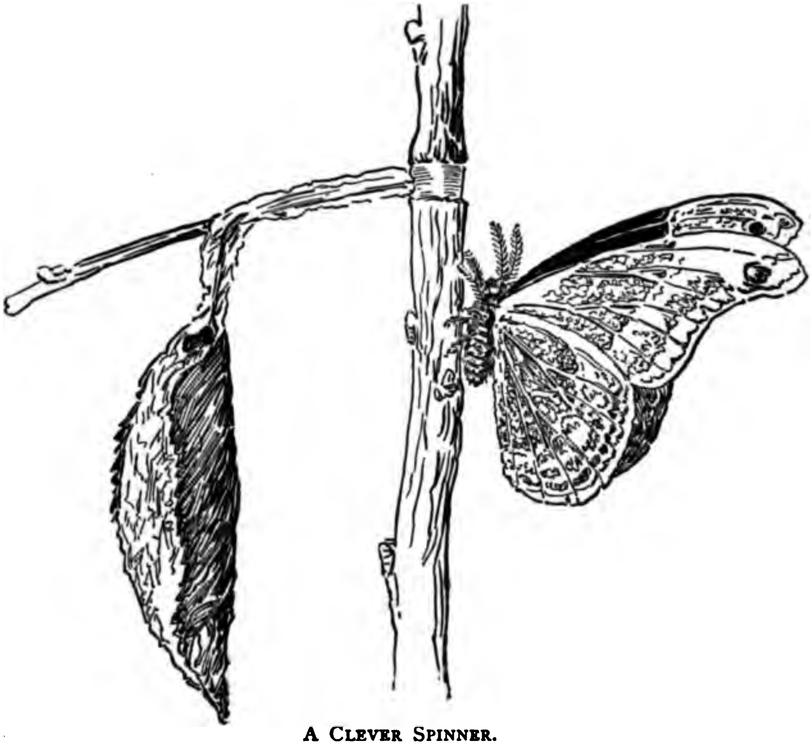
The water sprites are common in all swift streams in the northern United States. There are very many species and but few have been studied, so there are many facts about their curious lives yet to be discovered. No more common or better objects for observation are to be found in all the realm of nature study than these interesting little creatures.

A CANNY SPINNER.

Among all the insect spinners of silk indigenous to America the most famed and the most common are the giant silkworms. There are several species of these, and they are the caterpillars which later change to great and gorgeous moths; the most delicate and beautiful among these being the well-known luna-moth.

The subject of the present sketch is the most clever, though it is one of the smaller of the giant silkworms. It is the larva of the moth known as the *Promethea.* The female of this species has reddish-brown wings with clay-colour margins. The male is black above, and at first sight looks like a different species.

The promethea caterpillar feeds upon the leaves of many of our fruit and forest trees, but is not often dis-



A Clever Spinner.
(The promethea moth and his cocoon, showing the leaf fastened to the twig and the twig to the branch by a band of silk.)

covered because of the protection from observation which his green coat affords him. When fully grown he is usually about two and one-half inches long, and is bluish-green in colour, and is ornamented with tubercles of shining black. After he has attained his full growth through

the devouring of foliage of his native trees, he selects some leaf which he considers suitable and commences to fit it up for his winter abode.

How his blue-green highness should happen to know aught of autumn and winter and the falling of leaves must ever be a mystery to us, since he is hatched from his egg in the warmth of summer. He surely knows, though, for the first thing he does of a September morning is to weave a close web around the petiole of his chosen leaf, and then fasten it to the parent branch with a stout band of silk, thus making sure that no autumn wind will tear it away. Then he draws his leaf about him cloakwise and makes within it, around himself, a thick blanket of strong, warm silk. Being a seer as well as a worm he does not build his cocoon entirely closed, since when spring comes he knows he must push his way out when his body and wings are soft and flabby. So he cunningly makes a valve at the upper end of the cocoon which will later afford him egress. Having thus provided for two contingencies and thereby proved himself a true prophet he curls up inside his cocoon and changes to a pupa. There he swings in his leafy hammock safe from dampness and storm and safe from enemies; for what bird would think of looking for food in a withered leaf clinging to a bare branch?

The promethea caterpillar seems to know something of structural botany also. He knows the difference between a simple and a compound leaf, and he knows a twig from a branch. When he chooses a simple leaf like that of the lilac for his blanket he simply fastens the petiole of the leaf to its branch. But when he chooses a leaflet of a compound leaf like hickory for his hammock he fastens

the leaflet to its midrib and then fastens the midrib to the branch. In the case figured here the leaf is a simple one, but the clever fellow concluded that his weight was too much for the twig to which his leaf was attached. So he made himself doubly secure by fastening the twig to the larger branch. This exceptional case was chosen for illustration to show the strength of the silk. The cocoon was made two years ago, and the band of silk is so strong that the growing branch could not burst it, but grew around it as if it were of iron instead of the finest silk.

A most interesting and instructive lesson in nature study may be obtained by gathering the promethea caterpillars and feeding them in cages made by putting mosquito netting over branches of the food plant. Fresh branches may be given them from day to day, and they may be observed while they fasten their leaf hammocks and weave about themselves their winter blankets.

These moths recognise their mates from afar by some mysterious means unfathomed by our dull senses. It is an interesting experiment to place a female promethea in a mosquito-netting cage in an open window during an afternoon and see the great number of suitors that will gather around her prison seeking for her favour.

A LADY MASON.

She is undeniably a fashionable lady of the old school. This is proved by the remarkable slenderness of her waist; it outdoes in lack of size that of any lady that any fashion magazine ever dared to figure. But for all this extreme

emaciation at the waist line our lady mason is a strong and vigorous worker and her life is one of toil.

Most of the houses which shelter the young in the insect world are made by the mother for her children, and are a means of protecting them while they are young and unable to care for themselves. This being the case, it is not surprising to learn that among insects the question of woman's rights is settled permanently in the affirmative. With very few exceptions the insect husband and father is an irresponsible and care-free fellow, and the idea that he should help prepare shelter and obtain food for his children never enters his giddy head. On the other hand, the insect mothers often wear themselves out in unselfish toil for their young. It is a fact that among insects most of the carpenters and masons are females, who ply their trades for the sake of their young.

The subject of this sketch, *Eumenes fraterna,* is a cousin of the wasps known as the mud-daubers, and differs from them mainly in her superior skill and æsthetic sense. She is a graceful creature dressed in shining black and ornamented with yellow bars and spots; her wings are dusky gray, and she is armed with a strong pair of jaws, which she uses both for hod and trowel.

Some fine morning in early summer she selects some bush or tree that is conveniently near the banks of a stream, pond, or mudhole; the willow seems to be a favourite, probably on account of its water-side habits. On some twig of the chosen tree she begins the construction of her nest. Her material consists of grains of sand and gravel, which she imbeds in a cement prepared by mixing mud with a fluid which she secretes from her

mouth. This cement, when dried, is quite firm, although it is not so strong as the cement of the mud-dauber. When examined through a lens one of the walls of the new dwelling appears like that of a cobblestone house with a pre-

A Lady Mason.
(*Eumenes fraterna* and the plaster nest she builds for her young.)

ponderance of mortar and a minimum of cobblestones. She also understands the value of hair as a strengthening ingredient in plaster, and often uses any stray hairs that she happens to find to mix with her cement. She builds up her wall in circular layers, and has an eye for symmetry and beauty. She makes her little house nearly globular; not content with this, she must have a beautiful door, so she builds it up gracefully like the opening to an ewer. At this stage it bears a very strong resemblance to a Mexican water-jug on a very small scale. The nest is

rather rough outside, showing more or less plainly the layers of plaster and stone; on the inside it is very smooth and polished, and over it all is a fibre lining that looks like a thin coat of silk. As adult wasps have no means of spinning silk it has been suggested that this lining is spun by the larva after it hatches. But I have examined many nests with a microscope, and am convinced that the fibre lining of the nest is a part of the original structure. Possibly the wasp coats the interior of her nest with the fluid with which she mixes her cement, and this in drying splits up into silk-like fibres.

When the nest is nearly finished the wasp mother starts out on a hunt for provisions to store within it. She is keen-eyed, and she soon discovers some unwary caterpillar, upon which she pounces as a hawk would upon a mouse. The moment she seizes the caterpillar in her jaws she thrusts her sting into him, which soon puts a stop to his powers of squirming. The effect of this sting is magical, and as yet we do not know how to explain it. It paralyses the victim without killing him; and although he is unable to take any more food for weeks, the caterpillar remains as plump as at the moment he was stung; usually he is able to stir a very little, but often seems truly dead. Some hold the theory that the power of the wasp's sting lies in the place of its insertion; that she selects a certain point in the caterpillar's nervous system and stings it unerringly, thus bringing on paralysis. Others hold that with the sting some subtle fluid is injected into the victim's body which brings on paralysis and keeps the tissues from decay.

The wasp carries her helpless prey to her nest and

places him within it, and then goes hunting for more. From our standpoint she is a useful little creature, as she is partial to orchard pests, especially the canker-worm. When she has packed her little mud jug full of meat warranted to keep fresh until used she lays an egg in it, and then fills the neck of the jug with cement.

Very soon a little grub hatches from the egg and falls at once to eating his patent preserved food. His mother, whom he has never seen, and whom he is likely never to see, has shown excellent judgment as to the capacity of his little stomach, and has provided just enough food to nourish him until he reaches maturity. Then he changes to a pupa and passes this quiescent state in his mud house safe from all enemies. Finally he changes to an adult and gains his wings, and then he is so large that he completely fills the nest of his babyhood. He soon gnaws his way out through the side of his house, apparently never trying to push out the cork of the jug which his mother had cemented in so strongly.

Of course the work of the wasp mother has only begun when she finishes her first little house. She goes immediately at work to make another, and then another, and another. I do not think we know how many of these nests she makes before she wears herself out with toil. Sometimes she places several together on the same branch, but often she places them singly.

There are many interesting questions to be settled by the nature-study student concerning the habits of this interesting wasp. These are some of the questions:

Does she finish her nest entirely before she places the caterpillars within it?

If so, to what use does she put the carefully made mouth of the nest?

Does she construct her nest in even layers?

How does she make the fibrous lining?

How many nests does she construct?

Does she always sting caterpillars at a special place in their anatomy?

Any one who will answer for us these questions will add much interesting information to our present sum of scientific knowledge.

CORNELL UNIVERSITY.

IV. MOTHS, BUTTERFLIES, AND CATERPILLARS.

By Clarence Moores Weed.

What the bird is to the world of back-boned animals the butterfly is to the world of insects. Both are creatures of the air, and both in a peculiar way appeal to the fancy of mankind. The literature of all people is full of allusions to these embodied spirits—so graceful, so fragile, so full of life and action.

No insects are more fascinating as objects of pursuit than butterflies. They are easy to find, easy to catch, easy to mount, and easy to study. Under the microscope they reveal beautiful scales all over the surface of the wings, which over the rest of the body are mingled with hairs. They fly by day rather than by night, when most moths are abroad. But the most interesting thing about a butterfly is its life history, the marvellous changes which it undergoes in its development from an egg to a caterpillar, from a caterpillar to a quiet chrysalis, and from a chrysalis to a butterfly. This may well be illustrated in the case of one of our common swallow-tailed butterflies.

A BUTTERFLY'S LIFE STAGES.

The accompanying picture of the celery caterpillar shows the four stages of life through which all butterflies and moths pass. The adult butterfly is a handsome black creature, having yellow and blue markings on its wings. It appears in the garden early in summer, seeking out the celery, parsley, or carrot plants. When one of these is found she deposits a small yellowish egg on the under side of a leaf. In a week or so the egg hatches into a small caterpillar, less than one-tenth of an inch long. It is black, with two white transverse bands, one across the middle and the other at the hind end of the body. The back is roughened by minute black projecting points.

This little caterpillar feeds upon the leaf at hand, and soon so increases in size that it is too large for the skin with which it came from the egg. It is necessary for it to shed this skin or moult. So the skin splits along the back, and the caterpillar wriggles out, clothed in a new skin that has developed beneath the old one. On the new covering the colour markings are somewhat different. The caterpillar now continues to eat and grow for several weeks, casting its skin at intervals and changing considerably in colour and markings.

The full-grown caterpillar is represented in the picture on the leaf-stalk. Its general colour is pale green, with a series of transverse bands of black and yellow markings. Just back of the head there is a pair of peculiar yellow Y-shaped organs, which are generally not visible; but

when the caterpillar is irritated they are thrust out and emit a most disagreeable odour. They are probably useful in frightening enemies away.

In the course of a few weeks the caterpillar becomes full grown, so far as this, its "larva stage," is concerned. It now becomes restless and leaves the plant, seeking some sheltered situation where it can change to a chrysalis. When a suitable place is found it spins, as Dr. T. W. Harris has said, "a little web or tuft of silk against the surface whereon it is resting, and entangles the hooks of its hindmost feet in it, so as to fix them securely to the spot; it then proceeds to make a loop, or girth, of many silken threads, bent into the form of the letter U, the ends of which are fastened to the surface on which it rests on each side of the middle of the body, and under this, when finished, it passes its head and gradually works the loop over its back, so as to support the body and prevent it from falling downward." Its next move is to cast off the caterpillar skin, and thus enter upon the third stage of its existence—that of the "chrysalis" or "pupa." This is done about twenty-four hours after the caterpillar has hung himself up.

The insect remains in this chrysalis condition about two weeks. Then it is ready to change to the fourth stage of its life—that of the "imago" or butterfly.

The pupa skin cracks open and the butterfly emerges, with its wings undeveloped. They soon expand, however, and the cycle of insect life is completed.

Thus the butterfly has gone through the four great stages of insect life—namely: first, egg; second, larva; third, pupa; fourth, adult or imago. All the butterflies

THE LIFE STAGES OF THE CELERY CATERPILLAR.

and moths go through similar changes, which are called their "transformations."

The butterfly of this celery caterpillar is commonly called the asterias butterfly. It is one of the most abundant of the swallowtails.

BREEDING-CAGES FOR CATERPILLARS.

The way to find the most interest in butterflies and moths is to rear their caterpillars in confinement. To do this you should keep them where you can watch them from day to day. For this purpose you should use some sort of "breeding-cage," which is simply a closed vessel in which a caterpillar or other insect may be kept, so that it

CAGE FOR CATERPILLARS.

will go through the cycle of its changes where it may be seen.

A very good sort of breeding-cage for caterpillars is reproduced in the picture herewith. It consists of a common glass lantern globe, resting upon a flower-pot saucer nearly filled with sand or earth. Over the top of the globe a piece of gauzy cloth is held in place by a rubber band.

To start your breeding-cage, first get your caterpillar and a stem or leaf of its food plant. Place the latter in a bottle, which is to be set in me earth in the middle of the flower-pot saucer. The bottle is to be full of water to keep the plant fresh, and a cork or wad of cotton is to be stuffed into the mouth of the bottle to hold the piece of food plant upright and to prevent the caterpillar from falling into the water. At intervals of two or three days the food plant will need to be renewed, unless the caterpillar eats it all up, when, of course, it should be replaced at once. After this is done the caterpillar may be put upon the food, and the lantern globe placed over the whole. The bottle should not be so tall that it will prevent the caterpillar from reaching the food in case it falls off the leaves.

It is not necessary, however, that even so simple a cage as this be made, although such a cage has many advantages. The insect can be easily watched, the cage is readily cleaned, and there is plenty of fresh air for the caterpillar. But boxes with glass tops may be used instead, as also may common fruit jars, or for small insects even glass tumblers or jelly glasses.

THE CABBAGE CATERPILLAR.

One of the easiest caterpillars to obtain is the common green cabbage-worm. In the summer it is pretty sure to be found in almost any garden. When full grown it is about an inch long and half as thick as a common lead-pencil.

If you put half a dozen of these cabbage-worms in a glass can or some other breeding-cage, selecting caterpillars which are nearly full grown, you will be able to see them pass through the wonderful changes from caterpillar to butterfly. Keep them supplied with fresh cabbage leaves as long as they will eat. When they become full-fed in this larval stage of their existence each will fasten itself by the back end of its body in a little web of silk, which it first spins by means of the silk-glands in its mouth, and then will run a loop of silk over its body near the head end.

The caterpillar, having completed these preliminaries, will now become quiet for a time. Probably its body will shorten a little, and before very long the skin will split open on the back. Then there will follow more or less wriggling until the skin is thrown off and there remains exposed to view the "chrysalis." This chrysalis is a very different-looking object from the larva. It has neither legs, nor eyes, nor jaws. It is also different from an adult butterfly, having neither wings, nor "feelers," nor tube for sucking the nectar of flowers.

In summer your one-time caterpillar will be likely to remain in this quiet chrysalis state a week or ten days.

On the outside it is a quiet creature, but on the inside changes are taking place with great rapidity. A large part of the tissues of the caterpillar are being broken down and being built up into new tissues. It is a strange and wonderful development. At the end of it the dainty butterfly is fully formed, so that when in due time the skin of the chrysalis cracks open the butterfly emerges. The only thing lacking when it thus comes out are the large wings; about its shoulders are some odd little things, which are really the wings not spread out. Soon after coming out the butterfly rests upon some place where there is room for the wings to expand. The body juices are now forced into the wing veins and the expansion soon takes place. Then the butterfly is ready to go afield in search of flowers and playmates—a wonderful emblem of the possibilities of existence.

In this, its final stage, the butterfly is very different from what it was as a caterpillar. Then it did nothing but eat and grow, eat and grow. Now it needs only to quench its thirst with the nectar of flowers, to wander at will through the air, basking in the summer sunshine, to find a mate, and perchance to lay its eggs upon the leaves of cabbage or other related plants. These eggs are tiny things, but in each is the germ of a creature that is to go through the same marvellous changes that the butterfly has undergone.

MOTHS AND MOTHS.

The word "moth" is an extremely comprehensive term. To the housekeeper it brings to mind little crea-

tures found in carpets and woollens, making havoc in the closet and the attic. To the entomologist, however, it may bring to mind a great variety of creatures, from giant cecropia moths larger than our largest butterflies to tiny

THE ATTACUS CECROPIA MOTH.

moths so small that their structure must be seen through a lens.

The sphinx-moths are an especially attractive group of moths. Instead of flying only in the dark, as most moths do, these fly at dusk, visiting a great variety of flowers in order to sip nectar through their long tongues. The picture shows one of the commonest sphinx-moths, none the less interesting perhaps because it is the adult form of the common tomato-worm of the garden. Its life

history is fairly representative of the whole group of sphinx-moths.

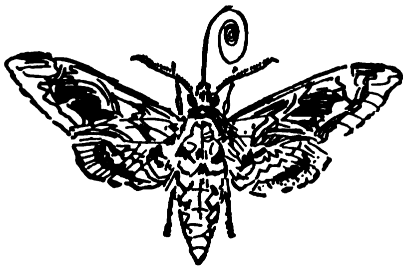
If you see a third or a half of a tomato vine in summer with its leaves gone and only the bare branches showing you may be sure that a tomato-worm is at work. Look a little, and you will be likely to find it. It is quite large, light green in colour, with several oblique whitish stripes along the sides of its body. On the back of the hind end there projects a peculiar spine.

CHRYSALIS OF TOMATO-WORM.

If you put one of these caterpillars into a breeding-cage and feed it with fresh tomato leaves you may see it grow to a length of about three inches. Then it will stop eating and enter the soil in the bottom of the cage. Had you left it out of doors it would go down some distance. Then it would pack the earth from itself in such a way as to form a cell, in which it would change to a peculiar chrysalis, having at one end a structure suggestive of a jug handle, as may be seen in the figure. This is the tongue case.

If the tomato-worm goes into the ground in autumn it remains in this quiet pupa state until the following spring. Then it wriggles upward to the surface, when the pupa skin splits open and the moth emerges. Its wings soon expand, and it becomes a beautiful creature of the form

shown in the figure. The most curious part of its structure is the long coiled tongue projecting from the front of the head.



MOTH OF TOMATO-WORM.

THE LUNA-MOTH.

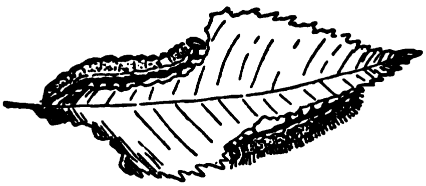
The most interesting of all our moths is the luna, or queen of the night. It is a glorious insect, with its delicate green wings expanding fully four inches. Along the front border there is a marking of purplish brown, and along the outer margins there is a marking of greenish yellow. The moth is of the form of a swallow-tailed butterfly. When it flies through an open window into a lighted room at night its beauty is sure to attract attention.

The eggs of this species are deposited on the leaves of various trees in early summer. The caterpillars feed upon the foliage, and late in summer or early in autumn spin their tough oval silken cocoons on the ground beneath their host plant. There they remain until the warmth of the succeeding spring calls them to life, when they come from the cocoons as marvels of insect beauty. The caterpillars are seldom seen, and in New England at least they are never destructive to a serious extent.

THE FOREST TENT-CATERPILLAR.

Another moth larva which has been attracting much attention of late is the forest tent-caterpillar. This pest has done great damage to orchards and forests during the last few years in several different States.

These caterpillars hatch from eggs deposited in cylindrical masses of a hundred or more upon the twigs. The young larvæ come forth from the egg in spring about the



FOREST TENT-CATERPILLAR.

time the leaves of the trees begin to unfold. When first hatched they are tiny creatures, scarcely one-tenth of an inch long, showing under a lens that the blackish body is provided with a covering of long brownish or grayish hairs. Wherever they go these little larvæ spin a silken thread which marks their pathway, although the thread is so slender that it is to be seen only through a lens.

The tiny caterpillars feed upon the tender leaves of the twig near where the egg mass was placed. In about two weeks each larva increases in size to such an extent that the skin in which it came from the egg is too small for it. This skin then splits open along the back, and the caterpillar crawls out clad in a new skin that had gradually

been forming beneath the old one. After this first moult the forest caterpillars begin feeding again, eating, of course, more and more of the leaves as they become larger. A week or so later they again moult, a process which is repeated twice thereafter at similar intervals. At the period of moulting the caterpillars congregate upon the trunk or larger limbs of the tree, often not far from the ground. Beneath the mass of larvæ there is an inconspicuous web, in which the feet are more or less entangled.

LEAF COCOON OF CATERPILLAR.

When the caterpillars become full grown each seeks a place in which to spin its cocoon. Many remain in the trees and tie up the leaves by silken threads, thus forming a partial or complete covering for the cocoon. Others seek crevices in the rough bark, while many others, probably one-half or more of all the caterpillars, forsake the tree and wander off in all directions, utilising any shelter they may come upon. They commonly crawl up the sides of houses and other buildings and form their cocoons along the clapboards or beneath the gables.

Soon after forming the cocoon the caterpillar changes to the pupa, an oval brown object without legs or wings, able only to move by a wriggling of its body. About ten

days later the pupa skin cracks open and a brownish moth emerges from the cocoon. This is the adult condition of the forest tent-caterpillar.

MOTH OF TENT-CATERPILLAR.

THE ARMY-WORM AND ITS MOTH.

Perhaps no member of the great group of night-flying moths is so notorious a depredator upon cultivated crops as the army-worm. This is a caterpillar-like larva that hatches from eggs laid by a handsome brown moth between the sheaths of grass blades. The young army-worms are green, but later they become ornamented with stripes of yellow, gray, and black. They feed upon the leaves of grass, clover, wheat, oats, rye, and other cereal and forage plants. They become full grown in about a month from the time of hatching.

The army-worms ordinarily remain concealed about the bases of grass or grain, feeding there unnoticed, but occasionally they become so numerous that the food supply is exhausted; then they are forced to seek other feeding grounds. It is at such times that the armies appear, and, moving in solid masses, they sweep all grasses and grains before them. The full-grown larvæ enter the ground and

pupate in earthern cells, emerging a fortnight later as moths. In southern latitudes there are several broods each season, while at the north there are usually but two.

The army-worm occasionally becomes frightfully destructive. Its voracious onslaughts were experienced more than once by the early New England settlers. Old records indicate that its ravages were noticed as early as 1632, and that the insect was injurious in 1646, 1649, 1666, 1743, 1762, and 1770. In more recent times this pest has often been destructive in many widely separated States.

V. FERNS, LEAVES, AND WOODLAND PLANTS.

By F. Schuyler Mathews.

The woodland is simply another world. Things get on there differently from the rest of creation. Here is convincing proof of the fact. The fern belongs to the woodland; botanists choose to call it a cryptogamous plant, because there is a mystery about it, an irregularity in comparison with the regularity of the rest of vegetation, a hidden truth which requires some digging out from concealment. The fact is that the fern produces no true flowers with stamens, pistils, and so forth, and it fructifies by means of spores (simple cells) instead of seeds.

If we examine the back of a fern leaf, let us say the one called common polypody (*Polypodium vulgare*), we shall find it spotted with terra-cotta-coloured grains. Here we are face to face with a strange fruiting principle; these grains are the spore boxes which finally split open and discharge the powdery contents called spores. Notice in my drawing that there are seven or eight of these little brown spots in a row; each one is situated at the end of a vein, or at a point where two veins meet. This fern is a pretty little affair about seven or ten inches high, stocky in character, evergreen, and simple in the leaf. It is a splendid

fern for cultivation, and it is found in the rocky woods northward.

The fern called the flowering fern (*Osmunda cinna-*

POLYPODIUM VULGARE.

momea) possesses quite opposite characteristics. Its so-called flowering nature is simply a matter to be referred to the distinct frond or branch which exclusively bears the

OSMUNDA CINNAMOMEA.

spore cells. This frond is not leafy, and the so-called fertile pinnæ upon it are so crowded together that the whole branch has a crushed-together brown appearance. The

sterile fronds of this fern grow from two to five feet high, and the leaflets, as may be seen by my drawing, are finely pinnate; *i.e.*, all cut up into fine leaflets. At first the short fertile fronds are woolly, but they soon grow smooth and wither away.

ADIANTUM PEDATUM.

Another, of totally different character from the two already described, is the dainty maidenhair fern (*Adiantum pedatum*), a shy recluse of the shady wood. The fruit-dots of this fern are on the leaves at the ends of the veins, borne upon the inner side of a reflexed portion of the margin.

The long, wiry stems of the tall fronds, from one to two feet high, are dark polished madder-brown in colour. The little leaflets are exceedingly dainty and delicate, and the branches spread horizontally exactly as one would spread the fingers of one's hand.

The oddest fern of all is the Hartford fern (*Lygodium*

Lygodium Palmatum.

palmatum), a climbing character scarcely less dainty than the maidenhair species. Its colour is pale green, and its little leaf is spread out as the fingers of a baby hand. The tiny little leaflets or frondlets are in pairs, and are of the usual cinnamon-brown colour. This is a rare local fern, common in the vicinity of Hartford, Connecticut, found in shady woods or tangled among the plants in some woodland opening.

LYCOPODIUM OBSCURUM.

Still other odd children of the wood pass by the name of Lycopodium. They are truly children in one sense, for they all creep! The common name for this curious little group is the club-moss family. I suspect the Virginia deer, if he could talk, might tell us more about the ever-

green Lycopodiums than the botanist; certainly he is very partial to them as a winter diet, and probably he knows the distinct flavour of each species. There are three of them which are quite common in our northern

Lycopodium Clavatum.

woods, where they may be found trailing along the ground, in and out among the roots of the evergreen trees and the dead pine-needles. One of the commonest species is called ground pine (*Lycopodium obscurum*); it grows in the moist woods north. The foliage is dark green, shiny,

LYCOPODIUM COMPLANATUM.

and the tiny scales are sharp-pointed. In appearance the plant resembles a miniature hemlock, about five or eight inches tall. The little perpendicular fruiting spikes, at first green and finally pale brown or yellowish, stand at the top of the plant. The horizontal creeping stem is about four feet long or less.

Club-moss (*Lycopodium clavatum*) is another common species. In shape the plant would suggest the general

appearance of branching coral, but a vegetable coral of a light-green tint, and soft to the touch. It is found in dry woods, and is especially valued as a Christmas green. The running stem is leafy and about six or seven feet long. Throughout the White Mountain region it is very common in worn-out pasture lands where young larches, pines, and firs promise a future forest. The powder, from the candle-like fruiting spikes grouped in pretty yellow clusters of two or three, is used by the druggist as a filling

CORNUS CANADENSIS.

for his pill boxes. If this powder is scattered about the flame of a candle, as soon as it catches fire it scintillates like miniature Japanese fireworks.

Lycopodium complanatum suggests in its leaf-form a bit of light-green arbor vitæ. It abounds in dry, sandy woods, where the evergreens are young, and it consequently has some slight chance of sunlight. It is frequently found in company with *Lycopodium clavatum*, and of the two it certainly forms the prettier carpet for the forest floor, because of its spreading horizontal branchlets.

Its running stems are distinguished by scattered, flat, sharp-pointed leaves.

In company with these Lycopodiums, and perhaps, most frequently in some moist locality, we will see the beautiful scarlet bunchberry (*Cornus Canadensis*), a startlingly brilliant little plant, which is at home in the depths of the evergreen forests that clothe the cool mountains of the north. Great patches of the handsome bunchberry decorate the mountain tops of New Hampshire, and certainly nothing could be more effective and charming than its splendid bright-red dotting the sombre brown and gray-green hues of the gloomy wilderness.

There is an infinite variety in the green of the forest leaves; few realise the extent of the variation. Early in May the budding leaves of the shagbark hickory are pale, delicate yellow-green, or green-yellow. I have watched the flitting about of the pretty little yellow warbler from stem to stem and wondered at the close resemblance of his yellow feathers to the spring foliage. Then it has occurred to me that the great French artist, Corot, with all his wonderful rendering of spring tints, failed to see the true beauty of the spring forests, for he failed to produce its pure green-yellow tints! But he did succeed in getting the sober tints of the aspens and alders, for these have a suspicion of solemn gray shadows in their makeup. But how short a time it lasts—this spring colour! A few days and it is gone. Then comes the monotonous green of summer. I say monotonous, but this is really not half of the truth. The fact is Nature is always full of variety; the brown-green of the spruce, the waxy deep green of the sugar maple, the silky green of the beech, the brilliantly

HERALDS OF SPRING.

(Skunk-cabbages well up, with patches of snow on the ground and a frozen pool beside them.)

From a photograph by A. R. Dugmore.

varnished light green of the gray birch, and the silvery shimmering green of the aspen—what could possibly be more variable than all these effects of the so-called monotonous green leaf! Truth to tell, the leaf is sometimes not green at all, and it happens that when we paint a picture of the forest we find pure green occurring—well, just here or there, where the sunlight catches the birch or the beech, and nowhere else; all the rest is a complication of hues modified by dusky shadows with which green has nothing whatever to do!

VI. BEES, WASPS, AND ANTS.

By Clarence Moores Weed.

Insects that live in societies have always been of peculiar interest to the human race, because men have seen in these colonies of lowly creatures conditions of existence suggestive of the wildest dreams of the philosopher and the philanthropist. The most notable insects which lead such colonial lives are the bees, the ants, and the wasps.

In a general way these colonies may be divided into two great groups—those which are permanent and those which are seasonal. The permanent colonies are those in which the colony remains fixed from year to year, as with the honey-bee and the ants, while the seasonal colonies are those which exist for only one summer, all forms but the female dying in autumn, as with the bumblebees and the wasps.

THE HONEY-BEE.

The honey-bee is probably the best known of the insects which live in colonies. For a very long time it has been utilised by man as a producer of honey, and its habits have been carefully studied in artificial hives by a great many observers. Doubtless originally the bees built their nests

in hollow trees or under overhanging cliffs, as those which escape from man do now. In Bermuda I have seen a large colony with its combs fastened to one of the inaccessible limestone cliffs along the shores of coral sand.

There are three forms in the colony of honey-bees—the female or queen, the males or drones, and the workers. The latter are vastly more numerous than the other forms.

HONEY-BEES.

Upon them devolves practically all the work of the colony —the gathering of nectar for honey, of pollen for bee bread, the secretion of wax and its construction into comb, the care of the young, and the protection of the colony from invasion by robber bees.

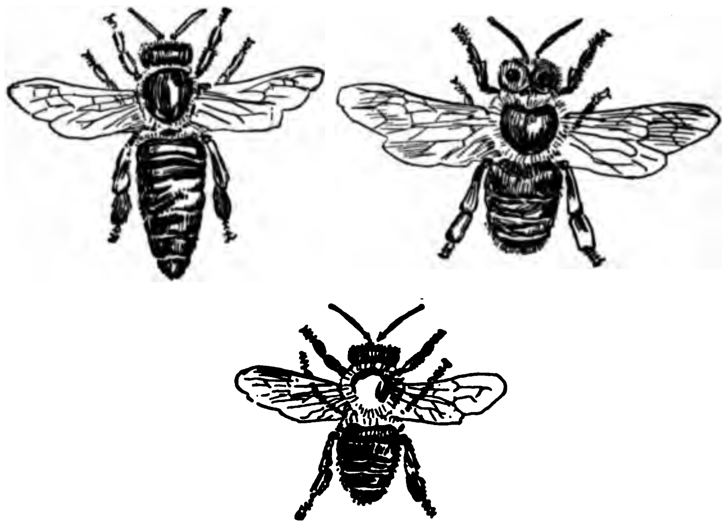
The workers are the smallest members of the colony. The drones are next in size, while the queen is the largest of the three. Each form is reared in a special size of cell.

The queen bee is queen in name chiefly. She is not a ruler in the sense that a human monarch is likely to be; she is rather the mother of the colony, laying the eggs

from which all the other members develop. She is attentively cared for by the workers.

THE BUMBLEBEES.

The bumblebees are among the largest members of the bee family, and are also among the most interesting forms. In spring you may often see the large queen bumblebee flying about. Sometimes she will be visiting the blossoms of willow or columbine or lilac, while at others you will see her flying close to the ground in a rapid zigzag manner.



QUEEN BEE, DRONE, AND WORKER.

This queen is the only member of the bumblebee colony

to survive the winter, and when she is thus flying close to the ground she is looking for an old mouse nest or some similar mass of soft materials hidden away where she can advantageously start the new colony which she is to produce. When, after much wandering, a suitable place is found, the queen makes a few cells, deposits an egg in each, and feeds the little white footless larvæ that hatch from these eggs upon the so-called bee bread—a mixture of honey and pollen.

These larvæ finally develop into worker bumblebees, smaller than the queen, which assist in building new cells and feeding the young that develop from other eggs laid by the queen.

In spring the only bumblebees you can find are the large queens, but by midsummer the smaller workers are to be found in abundance. Then you rarely, if ever, see a queen until autumn, when they again appear. The reason for this is that the workers are developed through the summer, but in autumn a brood of true males and females is produced. When cold weather comes, all forms but the females, or queens, perish, but these remain in the nest or find some suitable hiding place where they pass the winter.

THE USEFULNESS OF BUMBLEBEES.

Few people understand that the bumblebees are beneficial insects. Yet they are. As pollen-carriers for plants they do good service for mankind.

It is a strangely interesting fact that a large proportion of the flowering plants are especially adapted to certain special groups of insects. In consequence it is correct

to speak of some flowers as butterfly blossoms, of others as moth blossoms, of others as bumblebee blossoms. The common but beautiful columbine is an example of a bum-

THE COLUMBINE.

blebee blossom, and it is also an illustration of a plant especially adapted to one form of bumblebee, the queen. The nectar of the columbine is secreted in the five long spurs shown in the picture; the nectar is so far from the mouth of the blossom that it can only be reached by an

insect with a tongue as long as that of the queen bumblebee. So if you visit a field where columbines are blooming you will find many of these queens busily gathering nectar and pollen from the flowers. In return for these materials the bees carry the pollen from flower to flower and cross-fertilise the tiny ovules, which soon develop into seeds. There are many other plants for which the bumblebees perform this important service.

A STRANGE ADAPTATION.

One of the strangest adaptations between bees and flowers is that of the lady's-slippers. In the case of most flowers there is some sort of relation as to size between the blossom and its visitor, large flowers commonly attracting large visitors, and *vice versa*. Thus the good-sized columbine and the large queen bumblebee seem well fitted for each other. The lady's-slippers are large flowers, occupying much more space than the great majority of our blossoms, as may be seen from the picture herewith of the pink lady's-slipper. One would naturally think that a blossom of this size would have for its visitor insects of corresponding size. But as a matter of fact the visitors which pollenise them are very small bees.

These bees enter the blossom through the opening in front. They then find themselves in a large chamber, from which there is only one way of escape. This outlet is not the opening by which they entered, but another that leads the bee by the pistil and stamen in such a way that cross-pollination must be brought about as the bees go from flower to flower.

THE PINK LADY'S-SLIPPER.

THE LEAF-CUTTING BEES.

In the summer you may often find leaves of rose bushes with neat incisions where a part of the leaf has been removed. This is the work of one of the leaf-cutting bees, which carry the pieces to the place they have chosen for their nest. This may be a hole in the ground or a channel dug in some soft wood. The pieces of leaves are used to make cup-like cells, which the mother bee fills with pollen-

food before depositing her eggs. Each egg soon hatches into a footless grub that feeds upon the material about it until it becomes large enough to change to a pupa, later again changing to an adult bee.

These leaf-cutting bees have a special apparatus for

LEAF-CUTTING BEE AT WORK.

carrying pollen. Most bees carry pollen in the curious baskets on their legs, but these leaf-cutters have long hairs projecting from the under surface of the abdomen. The pollen is caught by these hairs and held in place as the bee flies from the flower to the nest.

THE WHITE-FACED HORNET.

The white-faced hornet is one of the most familiar members of the wasp family. It is an insect of good size, the body being black and more or less ornamented with white

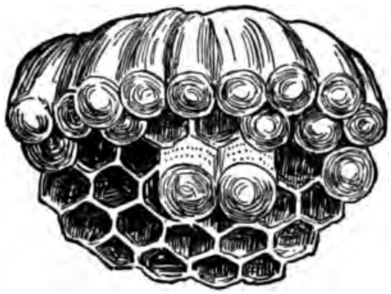
WHITE-FACED HORNET.

stripes. The individual wasps of this species which are found in early spring are the females or queens. Each is a queen without a retinue, however; not only has she no courtiers or servants, but she has no castle, not even one in the air, where no doubt she would prefer it. Consequently each queen has to become both the architect and the builder of her summer home.

In starting the home the queen wasp makes a few cells

NEST OF WHITE-FACED HORNET.

out of material derived from weather-beaten boards. In each cell she deposits an egg, and when the eggs hatch into small, white, footless grubs she feeds them with finely chewed insects which she has caught. Before long the footless grubs change to the quiet pupa state, to emerge later as wasps, similar in form to the queen, but considerably smaller. These are the worker forms of the wasp colony. Thenceforth the labours of the queen are less arduous, for the workers largely perform the duties



COMB OF HORNET.

of building the nest and rearing the young. The queen continues to lay the eggs, however, stocking each new cell with an egg as fast as the workers get it ready.

The nest of this species has an outside covering of paper-like tissue which protects the colony from rain and wind. As the nests are built upon the branches of trees such protection is very important. All through the summer the nest is enlarged, new layers of cells being built inside the nest by the constantly increasing colony of workers. At the end of the season the cells are made larger. In these a brood of male and female wasps de-

velops. The females live through the winter and rear a colony the following season, but the males and workers perish when cold weather sets in.

The white-faced hornets feed upon a variety of substances, but they make their chief diet upon other insects. Flies of various kinds are caught alive. Sometimes the wasp carries its victim to some perch from which she can hang by one leg to devour it, as shown in the accompanying sketch, which was made by Mr. J. H. Emerton, after observing the dining habits of one of these hornets.

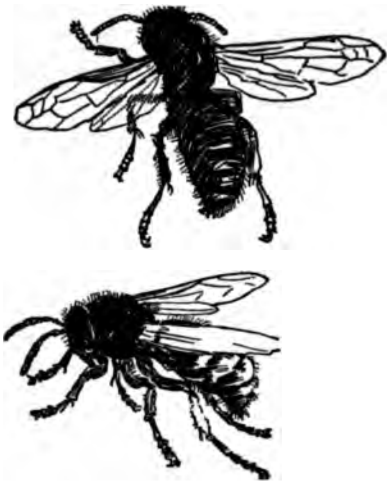
THE COMMON WASP.

Our commonest species of wasp is a black-and-brown creature that builds nests of a somewhat different pattern from that of the white-faced hornet. These nests have but one layer of cells, and may commonly be found under the gables of houses, the roofs of piazzas, in board piles,

WASP EATING A FLY.

and even under stones. The nest has no surrounding protection of paper covering, but depends upon the situation chosen to keep out the rain.

The life history of this wasp is very similar in its general features to that of the hornet. The females live over



EUROPEAN WASPS.

winter, each forming a few cells in spring in which she deposits her eggs. When the eggs hatch she feeds the young; rearing them so that they may assist in the domestic duties of the colony.

ANTS AND THEIR WAYS.

Since the days of Solomon the wisdom of ants has been proverbial. And the remarkable thing about it is that

modern investigations have shown that this wisdom is even more wonderful than the ancients supposed. That the ants store up food in their nests has been known from time immemorial, but that they have grain fields in which this food is grown is a fact of recent observation.

" If the statesman or the philosopher," writes Prof. J. H. Comstock, one of the most eminent of modern entomologists, " would study a perfect communistic society, let him throw away his histories of poor human attempts and go and study thoroughly the nearest ant-hill. There he will find no love for friend or wife or child, but a love for every one. There everything is done for the good of the whole, and nothing for the individual. The

A WINGED ANT.

state makes wars, provides food for all, cares for the children, owns all the property. He will find no complaint against the existing conditions of society, no rebels; but the fate of each one is determined by the accident of birth, and each takes up its work without a murmur. He will find that this perfect commune has developed courage, patriotism, loyalty, and never-failing industry; but he will find also that war, pillage, slavery, and an utter disregard of the rights of other communities and individuals are as prevalent as they are among our own nations, where selfish private ambition has held sway so long."

Like the other social insects, there are at least three forms in the ant colony. The female, or queen, is the

egg-layer. When first developed from the pupa she has wings, but after the wedding flight these are discarded. In some kinds of ants other additional forms are developed. In many species there are soldiers, with large heads and remarkable jaws. In many other species there are also two forms of workers—worker majors and worker minors, or big workers and little workers. In the wonderful honey-ant of our southwestern States one form is especially developed into a honey reservoir, with the body enormously enlarged.

ANTS AND APHIDES.

By turning over stones in pastures or on other grass lands you will often find colonies of small yellow ants, with their larvæ, and perhaps the cocoons containing pupæ. By careful observation you are likely to see upon the grass stems that intersect the colony small greenish-white insects, having the general appearance of aphides, or plant lice. Probably you will see some of the ants pick these creatures up in their jaws and carry them away, just as they do the larvæ and cocoons of their own species.

These are aphides, or plant lice. To use a well-worn phrase, they are the "milch cows" of the ants, being utilised below the surface of the ground in the same way that various ants utilise other aphides that live exposed lives on plants above ground. The commonest species in ants' nests on grass lands is the grass-root aphis. In the case of the corn-root aphis, the ants care for the aphides in the same way, and thus indirectly cause a great deal of damage to the corn crop.

INSECT PARASITES.

There are a great many insects closely related to the bees, wasps, and ants which have life histories of equal interest. In the order *Hymenoptera*, which these insects make up, there are many parasites, creatures which develop at the expense of other insects. A single example may serve to illustrate their history.

Late in the summer you may often find tomato-worms, as well as other sphinx caterpillars, which are more or less covered with small white oval objects, as shown in the accompanying picture. Perhaps if you did not know

CATERPILLAR, WITH COCOONS OF PARASITES.

the story of the caterpillar's life you might think these things were the eggs. But of course they cannot be eggs, for these are laid by the moth upon the leaves of the food plant.

These little silken objects have an interesting history, however, and a very unpleasant one, so far as the caterpillar is concerned. Some weeks previous a little black fly alighted upon the back of the caterpillar and laid inside his skin many tiny eggs. In a short time each egg hatched into a little grub that absorbed the body juices of the caterpillar. These parasites continued to grow at the expense of their unwilling host, the caterpillar, for some

time before they became full size. Finally they were ready for the next change; they burrowed through the skin of the caterpillar, and each parasite larva spun about itself a silken cocoon, inside of which it soon changed to a pupa.

So each white object is a cocoon and contains a pupa. About two weeks from the time the cocoons were made the pupæ change to flies, each of which gnaws off the end of its cocoon and comes out into the world.

The poor caterpillar lingers for some time in a half-dead condition before it finally dies, without completing the later stages of its growth.

VII. FROGS, TOADS, AND SALAMANDERS.

By Frederic P. Gorham, A.M.

Dame Nature is fond of giving object lessons. When she makes the tadpole change into the frog she is showing us to-day just what happened ages ago, when the world was young. In this simple way she is telling us that once there was a time when all back-boned animals dwelling on the earth were fishlike forms, aquatic in habit, breathing by means of gills, as do the fish to-day. No land forms had appeared. Great dismal forests of fern grew luxuriantly on the land—forests that later formed vast coal deposits—but there were no air-breathing vertebrates inhabiting them. On the other hand, the sea was filled with fish and fishlike forms. There was a great struggle for existence; anything that gave the least advantage to one form over another was immediately seized upon and made use of. Then it was that the first tadpole learned to leave the crowded waters, acquired limbs, and breathed the air of heaven. What a change that was! What advantage this animal had over its fellows! The land, with its verdant growth, was open to it; there were no enemies to dispute its sway. Is it a wonder that its development was henceforth rapid, and that it quickly

peopled the forests with a variety of forms? The evolution of land animals was then possible, and the results of that evolution we see in the innumerable forms of vertebrate life of the present day.

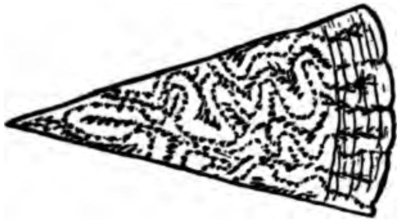
So the tadpole is a sort of " missing link " in development—a form connecting the fish with the higher and more complex forms of the land. And each spring as countless tadpoles change into frogs and toads and salamanders Nature is but going over again that very important step which she took ages ago—that transition from aquatic to aërial respiration which marked one of the most momentous epochs in the evolution of animal life.

Geologists have been able to learn something of these ancestors of all air-breathing vertebrates from their fossil remains. They were curious fellows. Nothing like them exists to-day. They resembled most, perhaps, the salamanders. They possessed short limbs—in fact, they were the first of the back-boned animals to change fins for limbs; they had long tails and probably a third eye in the middle of the forehead. In size they varied from a few inches to more than eight feet in length. Some of them were so highly developed that their remains were at one time taken for those of man himself, and they masqueraded under the title of " *homo diluvii testis* "—the man who witnessed the deluge.

The name " labyrinthodont " has been given to these early air-breathers because of the peculiar formation of their teeth, which resembled a labyrinth when examined in cross-section.

As the ages went on development progressed, and some of these soft-bodied labyrinthodonts gradually became

possessed of armour in the form of plates and scales, and claws developed on their fleshy fingers. These armoured forms were the first reptiles, ancestors of the lizards, snakes, and turtles of to-day. Those of the family which had not acquired armour soon lost their supremacy, yielding it to their more favoured relatives. As the reptiles rose in the scale of creation the labyrinthodonts proper were driven to the wall. The geological record tells us

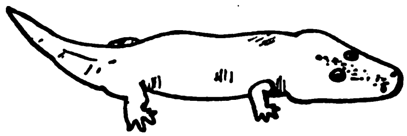


SECTION OF LABYRINTHODONT'S TOOTH.

that the labyrinthodonts soon passed entirely from the theatre of life, with the exception of a few insignificant forms which took refuge beneath stones, within tree stumps, or wherever they could find protection. It is this remnant of the race that is represented on the earth to-day by the frogs, toads, and salamanders, insignificant indeed compared with their ancestors that once dominated the earth.

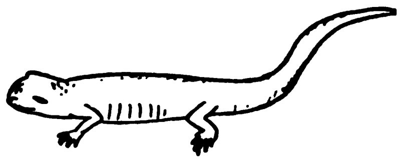
With this glance at the family tree of our humble friends, perhaps we shall consider them with greater respect because of their honourable ancestry, and because they preserve for us the record of that important step in the evolution of life, the transition from aquatic to land forms.

Because of this transition the name "amphibia" (*amphi*, double, and *bios*, life) has been given to the great class of the animal kingdom to which the frogs, toads, salamanders, and extinct labyrinthodonts belong. They lead a two-fold life, first aquatic, then aërial. The group



A LABYRINTHODONT.

includes all vertebrate animals with soft bodies, without scales or claws, breathing in youth by gills and later by lungs. It is intermediate, as we have seen, between the fishes on the one hand and on the other the scaly-skinned reptiles that never breathe by means of gills. It may be divided into several "orders," as follows: (1) The anura,

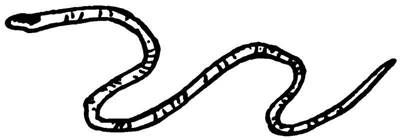


SALAMANDER (AMBLYSTOMA MACULATA).

which includes the frogs and toads, in which the tail is absorbed before adult life is reached. (2) The urodela, the newts, or salamanders, in which the tail persists throughout life. (3) The wormlike, limbless cæcilia. (4) The extinct labyrinthodonts.

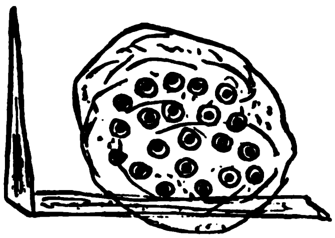
At the present time not a single amphibian lives in salt water. Almost all of them, however, live near or in fresh-

water ponds, swamps, or marshes. Even those adults which have no trace of gills are fond of water. Some forms have become arboreal in habit, as the tree-toads, while others are subterranean, as the cæcilians and certain toads.



A Blind Cæcilian.

The breeding habits of all members of the group are remarkably interesting. The eggs of the frog are common objects in every pond in early spring. They are deposited in large globular masses of jelly, from four to six inches in diameter, and are usually attached to reeds

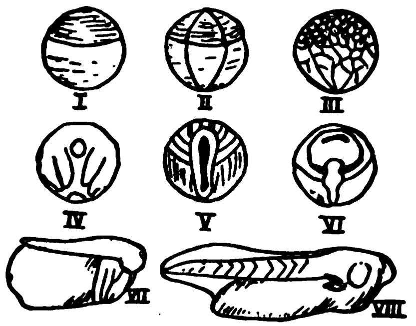


Frog's Eggs.

or twigs. Each mass of jelly contains many eggs. If we bring one of these egg masses home and place it in a jar of water, or, better, in an aquarium, where we can watch the eggs develop, we shall see a most interesting change.

When first deposited the egg is spherical, with a black-

and-white hemisphere. A few hours after deposition each egg has changed into a spherical mass of small spheres, resembling somewhat a mulberry. Then follow many changes, some of which are outlined in the figures above, and all of which can be observed with the naked eye or with a good reading-glass. At the end of from twelve to fifteen days the mature tadpole is formed, with head,

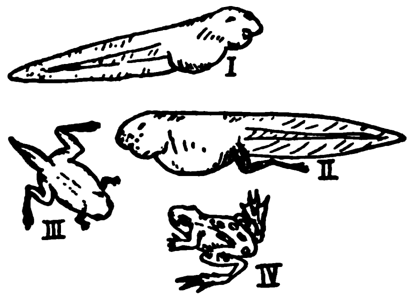


DEVELOPMENT OF THE FROG TADPOLE.

trunk, and tail. Of course the temperature has a great deal to do with the rapidity of development. Cold retards it, warmth hastens it. The water may freeze about the eggs, but if the eggs themselves are not frozen development again proceeds with the return of warm weather. The mass of jelly acts very much like the glass of a greenhouse—heat-rays once entering it are not allowed to escape, and consequently the temperature of the eggs within the jelly is warmer than the surrounding water, and development goes on though the water in early spring is very cold.

When first hatched the young tadpole has no mouth.

In a few days, however, the mouth appears, and it begins to feed hungrily on water-weeds or decaying vegetable matter. The tadpole grows larger and stronger. After a time, that varies considerably for the different species, limbs bud forth. The forward pair, hidden by the gill covers, do not become visible till some time after the hind limbs have acquired considerable size. With the increase in the limbs there is a corresponding decrease in the size of the tail, and by the time the limbs are functional and the frog is ready to crawl out upon land



FROM TADPOLE TO FROG.

the tail has nearly disappeared. At the same time that these external changes have been taking place internal ones, also, have occurred. The gills have given place to lungs; the intestine, once long and coiled and visible through the thin skin of the tadpole, has not increased proportionately with the body, and now is comparatively short and adapted for animal rather than vegetable food.

It is a question just how long it takes some of our frogs to develop from the egg to the adult. Probably the tadpole stage of some forms extends over two or three sum-

mers. More careful observations are required in regard to this point. In the wood frog (*Rana sylvatica*), however, it has been shown that but one season is required for its complete metamorphosis. In the case of our other frogs, the bullfrog (*Rana catesbiana*), the pickerel frog (*Rana palustris*), the leopard frog (*Rana halecina*), and the green frog (*Rana clamitans*), the exact time is not known.

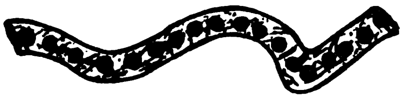
SALAMANDER'S EGGS.

When we are looking for frogs' eggs we may come across masses of eggs answering the description given above, with the exception that each egg in the jelly mass is surrounded by two circular envelopes instead of one. These are the eggs of the salamander, known as *Amblystoma maculata*. They develop into tadpoles just as do the frogs' eggs. The external gills of the newly hatched larvæ are more prominent, however, than in the frog larvæ, and the salamander tadpoles never lose their tails, but the legs bud out and the gills are absorbed before the adult condition is reached. The changes of these forms also can be watched in an aquarium.

The common toad (*Bufo lentiginosus*) lays its eggs in quite a different manner. It is a little later in the spring that the toads mate, and not until the latter part of April

are their eggs to be found. It always astonishes some people to be told that toads seek the water to deposit their eggs, and that the eggs hatch into tadpoles as do those of the frog. But this is the case.

One of the most characteristic sounds of the spring is the " whirring " of the toads in some roadside pool. The toad is not so particular about the kind of pond in which it deposits its eggs as is the frog. Any shallow pool, possibly one that dries up entirely in the summer, is acceptable. The toad prefers warm, shallow water, and his transformations are all over by summer time.



TOAD'S EGGS.

The adult toad spends but a short time in the water. During a single night perhaps all of the eggs of a season will be deposited. It has been estimated that a single female toad, inside of ten hours, may lay as many as 28,000 eggs, an average of over forty per minute for ten hours.

The toad's eggs are readily distinguished from those of the frog or salamander. They are laid in long strings of jelly, often yards in length. Each string of eggs resembles a necklace of black beads in a cylinder of glass. Each egg is about the size of a pin's head. These strings of eggs are festooned from water-weeds and sticks, or stretched along the bottom of the pool.

The rapidity of development of the toad's egg also depends on the temperature, but all their changes occur much more quickly than do those of the frog or sala-

mander. On this account they are most interesting to watch in the aquarium, and the full-formed toads can be reared with no difficulty. Some toads' eggs deposited this year on April 24th hatched into tadpoles on April 27th, and some time in May these little fellows ought to develop legs, and by June they will leave the water, comical, little, brownie-like toadlets no larger than peas.

The tadpoles of the toad can be distinguished by their small size and black colour. The tadpoles of the frog and salamander are larger and lighter in colour. The toad tadpoles complete their larval life while very small. The frog and salamander tadpoles, on the other hand, grow quite large before they take on the form of the adult.

The little toads, when they leave the water, migrate long distances in every direction in enormous numbers. They travel mostly at night, and emerge from their hiding places on dark days or after a shower, thus giving rise to the common impression that they have fallen with the rain.

These are some of the facts already known concerning these denizens of our swamps and marshes. There is still much to be discovered. Let some student of nature direct his attention to these humble forms and unravel some of the problems connected with their habits and life history.

VIII. WHAT BIRDS DO FOR A LIVING.

By Charles C. Abbott, M.D.

Nesting over, there comes no playtime for the birds. Either what is demanded of them by inexorable nature is viewed in the light of a pastime, and so our own idea of labour is not conceived by them, or they work hard and long for a living. Birds, however, are so cheerful under their lives' ordinary circumstances that they probably take the roseate view of existence. An unhappy bird is a contradiction, as we look upon them, in field and forest, notwithstanding that "the moping owl does to the moon complain."

There appear to be few impulses governing a bird's life after nesting duties are over. The first and all-important one is their food supply, and all else is more or less closely associated with this; and as birds are practically everywhere, this supply of food consists of a vast range of animal and vegetable products, and with such variation of character comes equal range of ingenuity in securing it; for with the search for every worm or seed devoured is the thought on the bird's part of a possible enemy lurking near. This latter condition is what sharpens a bird's wits, and has at last succeeded in making them more intelligent than many a mammal, which, being higher in the scale of life, ought to be smarter.

Rose-breasted Grosbeaks.
(By permission from "Bird Neighbors.")

It must always be remembered in studying birds that they have been longer on earth than mankind; that they spread over it and fitted themselves to its various physical conditions, and by exercise of intelligence were able to maintain themselves with moderate success. Savage man, with all his appliances and persistence, did not materially lessen the number of birds, although every species probably was looked upon as available for food. As time rolled on and civilised man began changing the face of the earth, conditions were to be faced that taxed many a bird, and the result was that some species left their old haunts, unable to cope with man's encroachments, while others were equal to adapting themselves to the new order. As an instance, when the hollow trees were gone, our common swift took to building nests in chimneys, and we all know how, without effort on our part, birds have become semi-domesticated, as in the case of the familiar English sparrow. Here let me say that practically all of our small birds would take kindly to the surroundings of our country homes and even city yards if not unnecessarily disturbed. Small birds are naturally trustful, and will come nearer and nearer until their confidence is abused. It is a fact that the uninteresting and often annoying English sparrow was not needed in our cities at all. Our native birds would have rid the trees in our streets of measuring-worms had they been given a chance, but indifference and ignorance had long carried the day, and not an oriole, tanager, or even a robin was safe in town. Under the very noses of policemen boys were allowed to stone the few birds that ventured into town, and were quite as willing to aid as to prevent a boy robbing a nest.

In seeking to gain their own living birds aid us in procuring ours. There is no other agency so powerful for providing for that balance in nature which, if greatly disturbed, leads to disaster. A plague of insects can be averted if there be birds enough about us, and we need fear no plague of birds in these latter days. The time was when thousands of blackbirds would settle on a cornfield and do considerable damage, but these same birds were easily frightened off, and at other times of the year were a blessing, considering the immense amount of noxious insect life they destroyed.

During the latter part of summer, when the young broods of the season are, like their parents, self-dependent, there is offered to the young naturalist a wide field for observation in watching the habits of these birds and their many exhibitions of ingenuity in securing food. If we knew our immediate surroundings as birds know theirs we should be most excellent naturalists. Birds notice everything. They see and hear movements beyond our powers of detection. Crawl over a grass plat and see how many worms you can find; yet the robin near by is pulling them from the sod at almost the rate of one a minute. Tap against a tree and listen and you will hear no suggestive sound; but the woodpecker taps and then says to himself, "There is a grub in there," and proceeds to dig it out. The house wrens at my home long since learned that there are more flies about the kitchen than the parlour, and they are far more apt to enter the former room than the latter. The English sparrows know when the little chickens are to be fed, and follow me to the coops, or, in the winter, mingle with the poultry and try as best they

can to swallow entire grains of corn. The barn swallows find their food in the air, and sharp indeed must be their eyes to detect the swift-winged insects in the upper regions, almost in cloudland, yet at brief intervals they return and show that they have captured living prey; and then, when the atmospheric conditions are so changed that insect life takes shelter, these birds will flit through the barn and stable in search of flies, always to be found there, and also gather many an unwary spider, picking it deftly from its web. The young naturalist can spend a profitable day, however, late in the summer, watching the birds in search of their food. It must be remembered, too, that these food-gathering habits change with the seasons, and while with many birds it is a matter of insect-chasing in the early summer and while the young are to be fed, in the latter half of the season, when the seeds of plants are ripe, many birds change to a vegetable diet. Even swallows, late in September, when moving southward, have been seen to eat the seeds of the sweet-gale.

Naturally every object that is digestible at all is utilised as food, yet poisonous matter is apparently avoided. The result of this wide adaptability of bird life is that birds eat birds, and some even largely depend upon decomposed animal matter, such as vultures and certain sea-birds. To see a hawk pounce upon a song sparrow and devour it is too painful to dwell upon. From our point of view it is one of the inconceivable cruelties with which nature abounds, and I pass it by; but when we see a turkey buzzard, a true vulture, gorging itself with the rotten carcass of some animal, we wonder how it all came about. Most strange is the quickness of this bird to detect the presence

of a dead animal. A sheep lying in a field is readily seen, of course; but only a few days ago I discovered a small dog that had been killed and was lying in my lane, under a large tree, and with a rank vegetation all about it. It was so inconspicuous I had never before noticed it, and yet, strolling in that direction, I chanced to see a turkey buzzard sitting near by and watching my approach. I stood still for a considerable time, but the buzzard was not satisfied that my intentions were not aggressive and it flew majestically away. What keenness of the sense of smell was here illustrated, for by no other means could it have been guided to the spot. As for myself, I could scarcely detect any odour, for the air was heavy with the perfume of apple blossoms and lilacs.

To turn to pleasanter aspects of bird life, there is the remarkable "dipper," found on the Pacific coast, that dives to the bottom of rapid mountain brooks and runs along the pebbly bed, finding food that most people suppose was reserved for the use of fishes; and this same bird will build a nest on a shelving rock behind a waterfall, and so have to pass through it going and coming. When we realise how big and varied the world is we wonder why a bird should become almost as aquatic as a fish. Again, our fish-hawk has no desire to attack small birds, and lives exclusively on that form of life which gives rise to its familiar name; and our bald eagle has so keen an appetite for a fish diet that it robs the hawk whenever it can, and often condescends to eat the half-rotten herring on the river shore, left there by the fisherman when the season is over.

As the summer wears away a change comes over the

dreams and the actualities of birds. The nights are cooler. Insects are less abundant and seek shelter, and the beginning of a marked change is noticeable. The swallows are no longer high in air and restless as the passing breeze. They gather in great companies, and sometimes sit upon a telegraph wire until not a bit of it is to be seen from pole to pole. They chatter incessantly, and, as I

GOLDEN-WINGED WOODPECKER.

honestly believe and have always insisted, they are discussing the situation in all its bearings. They came in the spring when food was sure to be abundant; now it is less so, and the time for departure has arrived. The birds are not long making up their minds. To-day they are here by the hundreds, to-morrow all are gone. The young naturalist, or older ones either, will see no change sufficient to warrant the exodus, but the world as seen by swallows' eyes is a different matter. Birds know a good deal about which man knows nothing. Ornithology, or the study of birds, is still somewhat a matter of guesswork.

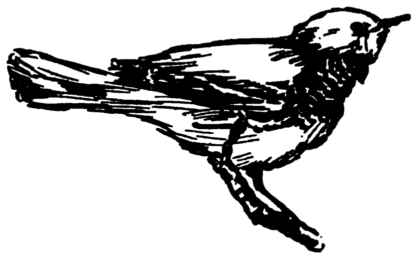
The departure of our summer's swallows early in September is the beginning of a change that every one realises a month later, for then the woods are more silent and

CROSS-BILLS FEEDING ON THE GROUND IN FEBRUARY.

From copyrighted photographs by A. R. Dugmore.

fields give an impression of being deserted. The thrush, the rosebreast, the flycatchers, the warblers, and whip-poorwill are gone. The little green herons have left the meadows and the clump of trees in which a colony of these birds nested. No matter where we wander, we miss our familiar friends of the long summer days. They have gone to southern and warmer regions to escape the rigours of the coming winter. This is called "migration." It is one of the remarkable features of bird life that has given rise to endless discussion, and the end is not yet. We still are in the dark as to when it commenced and what was the initial motive. Some of its features are extremely striking because of the expenditure of unnecessary exertion. Many what we consider weak-winged birds fly almost the distance from pole to the equator, when surely there are vast interlying areas that would meet their needs. Whatever gave rise to migration originally, the food supply has largely to do with it now, and this change of territory, momentous as is the undertaking, is one of the yearly incidents in the lives of many birds, but not of all birds. There is a goodly number that have proved equal to withstanding "the samples of weather" which do duty for climate in this country, so that at no time are we without birds, and very desirable ones at that. All winter long the song sparrow is cheerful as a May morning, and the cardinal redbird, seen against a background of untrodden snow, is a sight to be remembered; but this is not all, for there comes from the north a goodly number of birds to winter with us, because their own homes are too bleak for them during the year's short days. Snowbirds, golden-crested kinglets, titmice, horned larks, and

nuthatches, with whole hosts of tree sparrows, come trooping down from Canada, and on many a bright winter morning the frost-bitten fields and leafless woods are fairly alive with a cheery throng that makes merry in an infectious way; and if the thermometer ranges very low I am quite oblivious to the fact. Winter sunshine in the



BLACK-THROATED WARBLER.

woods is something too few of us appreciate, but when with it we have birds in abundance, as is often the case, it is a return after a fashion of the departed summer, and the true conditions are half forgotten.

Every bird, through inherited instinct, instruction from parents, and personal experience, knows that enemies continually surround it, and however pressing may be the demands of hunger, it bears in mind the possibility of being surprised, and is therefore quick to scent danger. I do not mean literally it smells the approaching foe, but it sees and hears what our own eyes and ears would never detect. Often have I seen a bird suddenly stop, crouch down, or creep beneath a broad leaf and remain motionless. Directly after the shadow of a hawk passed over or the bird itself swooped by, striking where it thought

its prey might be, and then circled outward into the open air with a shrill note of chagrin. No wonder the little warbler or wren was so eager to hide, for a bird-hunting hawk is the very acme of ferocity; far more so, so far as little birds are concerned, than are man-eating tigers to ourselves. The peaceful woods, as we call them, are over-full of tragedy, but happily we are not often witnesses to these under-sides of things. The storms are never of long duration, but days of jolly sunshine are many.

While little birds are timid and avoid being surprised, they also know when they have their foes at an advantage, and then are very brave, as well as impudent. Let them find an owl in the sunshine, blinking and bewildered, and they will roundly berate him. The hubbub is extremely amusing. We can bring this occasional natural occurrence about by placing a stuffed owl in a bush and then patiently awaiting events. The first small bird that comes by will stop, stare, and give an alarm call that all the bird world knows. Not one within hearing but will respond, and the result sometimes is that we see birds that we had previously overlooked. The excitement does not readily pass over.

A BIRD'S NEST AS A HOME.

After the nest is finished there is a brief period of comparative leisure, which the male bird thoroughly appreciates, and now his singing is at its very best. His mate has the nest more in mind than he does; but in a short time a complete change is effected. The eggs are hatched, and serious duties devolve upon the parent birds. Hap-

pily, though ever anxious they are never despondent, and if a moment of gloomy doubt arises they cut it short with a song; for even the female, which usually only chirps, will at times now twitter so earnestly that it approaches the dignity of a song. The one thought of the parent birds is to feed the young, and how great a quantity of food is required to nourish from three to five young birds can only be realised after patiently watching the constant going and coming of the parents. Sharp eyes are indeed necessary to discover promptly the proper food, which is not every available worm or insect. There is some selecting required, for birds but a day or two old are not fed upon objects that supply their needs when nearly ready to leave the nest. The appetite of a nestling is simply marvellous. A worm or insect every minute of daylight seems not too much, and I have often wondered that the parents' energies were not overtaxed, yet this does not seem to be the case. Observing a robin's nest carefully, under most advantageous circumstances, I found that the parents brought twenty-seven earthworms in an hour, dividing them among three young birds. The young were fed, I think, alternately, and no one got more than its share. The worms averaged four inches in length, so that here we have one hundred and eight inches of animal food, which, equally divided, made a yard of worm for each bird per hour. This was kept up pretty much all day. The robins ran about the grass plot and garden, and seemed to find the worms without delay or difficulty. If I needed a single worm for fishing it was necessary to use a spade and overturn a sod, sometimes several of them, before I could get one. The same is

Young Bluejays in Nest.

true of smaller birds, that feed exclusively on insects or their larvæ. The swallows visit their nests with such frequency it seems incredible that in the intervals of absence they can find sufficient food for themselves and young.

The parent birds have other duties quite as imperative. When the young are without feathers they have need of protection, and so one or other of the old birds must cover them, and the natural enemies of every bird must be guarded against. Nest-robbers are many. Snakes, squirrels, wood-mice, owls, and some of our larger birds, as crows and bluejays, are ever on the watch and devour many a brood.

There is another phase of the subject that young naturalists will discover in the course of their field work, which is difficult to explain, unless jealousy and selfishness have to do with it. Many birds have been seen destroying nests out of pure love of mischief; simply destroying without devouring the eggs or young. This ugly propensity is the blot upon the character of many a species that, as we see it generally, appears to be the very type of amiability. The turtle-dove is ill-tempered at times, and with the exception of the common house-wren no bird will savagely attack others as readily as the humming-bird. The slightest interference rouses its wrath, and even people have been darted at and scolded roundly when a nest has been approached.

This eagerness to defend the nest has its advantages so far as the observer is concerned. By it he is guided to the very spot and finds that of which he was in search; but to make the discovery valuable, infinite patience and

THE SMALL BIRDS MAKE A DISCOVERY.

tact are required. The bird's confidence is to be gained, and this is not a matter of an hour or of a day. Let the mere fact of locating a nest be sufficient at the time. Return the next day very carefully and approach a little nearer. Make no demonstration, and if possible keep your hands behind you. The third day you will find your presence creates less commotion, and on the fourth or fifth the birds will be satisfied that you mean no harm. Then studying the habits of the birds whose home you have found becomes comparatively easy.

The interest centring about a nest of young birds increases as the day of the brood's departure draws near. The parents are very anxious; and well they may be, for their incessant chattering, as if giving the brood endless instructions, attracts a good many unwelcome visitors. The young birds are very apt to reach the ground in their attempt to fly from branch to branch of a tree, and generally there is a cat ready to make a fatal spring, if the nest is near the house, or a snake, weasel, or crow is on the alert, if the nest is far afield. A knowledge of these dangers increases the ingenuity of parent birds, and the observer has frequent opportunities of witnessing unexpected occurrences, and goes away abundantly satisfied that birds generally know more than is supposed. This period of excitement and commotion is not true of all birds. Some are very methodical and undemonstrative. There is a colony of little green herons in a sink-hole in one of my fields. The birds come, regularly, late in April and build their flimsy nests of a few sticks, but I never can see them at work. Then comes the period of incubation and the appearance of the young. Later these half-feathered,

awkward fledglings perch upon horizontal branches and gradually grow strong and become like their parents, but there is never any excitement nor demonstration. Poor-sighted people might take the young for crooked twigs of the trees upon which the birds are resting. At last, to all appearances, they are equal to flying, but they do not stir. Day after day I watch for them to begin the use of their wings, but all in vain. Then I go again some morning, and every bird has disappeared. I have to confess, though I have watched the same heronry for many years, I have never seen much. It is very different with the larger night-herons or qua-birds. These are noisy enough, and generally it is " lively as a circus," as has been said of it; but, then, we have birds of somewhat different habits and often a hundred nests built very near each other.

The deserted nest is not an unattractive object. Generally it has not suffered by long occupancy, and now can be examined as to its structure just as well as when the birds finished it. In so doing, note well by what means the structure has been secured to the spot where placed. Sometimes there will be found evidence of considerable engineering skill, as when additional strength has been added by the attaching of strings to distant branches. I have seen this done by orioles and the red-eyed vireo.

Once left by the brood and parents, most nests are not revisited, nor is the same site chosen for a second brood; when this occurs the old nest being touched up. Yet there are, of course, exceptions. The pee-wee flycatcher keeps the old nest for years. So do fish-hawks. House-wrens return season after season to the same box, but make a new nest for each brood.

IX. BUGS AND BEETLES.

BY CLARENCE MOORES WEED.

To most people anything of small size that crawls or flies is a bug, but to those who pay attention to these creatures many of these bugs are beetles. For to the entomologist the word bug means an insect having certain definite characters which separate it from other insects. The true bugs form an order called hemiptera, or half-winged insects, because in the typical forms the basal half of each front wing is thickened, while the outer half is very thin.

But even when the application of the word is very restricted there are a great many sorts and conditions of bugs. Possibly to some people a certain domestic variety may come to mind as the typical bug, but a better example is found in the large creatures which during recent years have been called "electric-light bugs" because they are frequently about street lights. One of them is represented in the figure herewith.

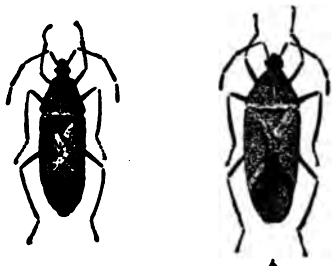
When these bugs are at home and not flying over the country to be dazzled by the lights, they are found in ponds and sluggish streams. On this account they are often called giant water-bugs. They are the giants of their

tribe, being the largest forms of the true bugs. They feed upon fishes, as well as various aquatic insects. Where the mouth should be there is a strong beak, with which the unfortunate victim is pierced after it has been caught between the clasping front legs of the bug.

The eggs of these giant water-bugs are laid in damp places along the borders of the pond. The young live in the water, preying upon such insects as they can catch.

THE SQUASH BUG.

The squash bug is one of the most familiar examples of the true bugs. These bugs pass the winter in the adult state, so that they are ready for the tender plants as soon as they appear above ground. When the squash leaves



a *b*

SQUASH BUG.

(*a*, male; *b*, female. Natural size.)

develop the bugs deposit their brown eggs upon them. These soon hatch into little bugs that suck the juices from the leaves. As the bugs grow they cast their skins occasionally until they become fully developed.

THE PERIODICAL CICADA.

One of the most famous examples of a true bug is found in the seventeen-year cicada, often called the seventeen-year locust. A better name is the periodical cicada.

The fully developed cicada has a wing expanse of about three inches. The veins of the wings are of an orange-red colour, as are the legs and rings of the abdomen. The male cicadas are provided with a musical apparatus on each side of the body, which acts like a kettle-drum when the wings are rapidly vibrated. The females, however, are not provided with this apparatus, so that they can take no part in the deafening chorus of their mates.

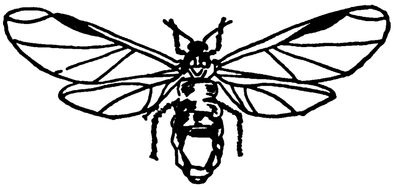
These adult cicadas appear in summer. Soon afterward the females make slits in the twigs of various fruit and shade trees and deposit therein pearly white eggs. One cicada will lay several hundred of these eggs.

A few weeks later these eggs hatch into strange-looking creatures that drop to the ground and bury themselves in the soil by the aid of their strong, peculiarly formed feet. Here they subsist upon the juices of various plants for many long years. Some broods of adult cicadas are thirteen years apart, while others are seventeen years apart.

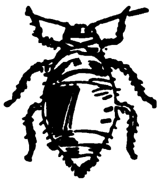
MARVELLOUS RATE OF MULTIPLICATION.

The reason why such tiny creatures as insects are often able to do so vast an amount of damage is because of their marvellous powers of multiplication. This is best illustrated, perhaps, in the case of the plant lice, or aphides.

These little creatures are known to many people under the name of the " green fly " of houseplants. In brief, the normal life-history of these little creatures is this: In the spring there hatches from an egg deposited the previous autumn a little aphis, which sucks the sap of its food plant for a number of days—sometimes a fortnight—before it



A WINGED PLANT LOUSE.
(Magnified.)



A WINGLESS PLANT LOUSE.
(Magnified.)

becomes full grown. During this period of growth it moults or sheds its skin a number of times to provide for its rapidly increasing size. Upon reaching maturity this plant louse commences to give birth to living young, a process which is continued for several days. The young resemble the mother, except that they are smaller. Each young aphis begins sucking sap on her own account, and in the course of about ten days becomes full grown and commences to give birth to other young. Thus the pro-

cess is continued through the summer, until in autumn a generation of true males and females is developed.

In a recent article upon plant lice Dr. J. A. Linter, the lamented State entomologist of New York, has given this graphic statement of the powers of multiplication of aphides:

"Professor Riley in his studies of the hop-vine aphis has observed thirteen generations of the species in the year. Now if we assume the average number of young produced by each female to be one thousand and that every individual shall attain maturity and produce its full complement of young (which, however, can never occur in nature) we would have as the number of the twelfth brood alone (not counting those of all the preceding broods), ten sextillions (10,000,000,000,000,000,000,000) of individuals. Where, as in this instance, figures fail to convey any adequate conception, may I ask you to take space and velocity as your measures? Were this brood, as above given, marshalled in line with ten individuals to a linear inch, touching one another, the procession would extend to the sun (a space which light traverses in eight minutes) and beyond it to the nearest fixed star (traversed by light only in six years), and still onward in space beyond the most distant star that the strongest telescope may bring to our view to a point so inconceivably remote that light could only reach us from it in two thousand five hundred years."

THE BEETLES.

The beetles form an order very distinct from that of the bugs. If you catch a May beetle and look at it very carefully you will find that the front wings are hard and horny, forming a protection to the membranous second wings. The mouth parts are formed for biting rather than for sucking, while the young stage is very different from that of the adult. These various characters go to form the

great group of sheath-winged insects called by entomologists the *Coleoptera.*

THE LADYBIRD BEETLES.

Few beetles are more generally known than the trim little ladybirds, with their round or oval forms and their bright and attractive colour combinations. Red, black, and yellow are the fashionable colours with these lady-

LADYBIRD BEETLES.

birds, which are to be found in a great variety of situations. In their beetle state they feed upon small soft-bodied insects of many sorts, but are especially fond of aphides or plant lice.

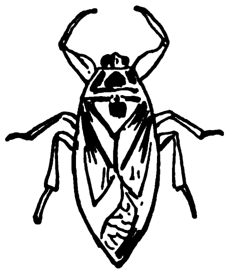
The young or larval ladybirds are very different looking creatures from their parents. The young hatch from eggs laid upon the leaves or branches of many plants. The eggs are small and yellowish. The larvæ have six legs, with which they move actively about. They are generally covered with bristly hairs. Like their parents, they feed upon other insects, especially plant lice. When they become full grown each larva attaches itself to a leaf, or a piece of bark, where it changes to a strange-looking pupa. In this condition it remains ten days or so, and then emerges as an adult ladybird.

THE TIGER BEETLES.

When you walk along a shady road in summer you are likely to see, if you watch, a rather small insect fly up in front of you and alight a few yards ahead. If you have an insect net and can use it dexterously you may be able to catch one of these creatures. You will find it to be a beetle, having the general form of the picture marked "tiger beetle" herewith. The head is quite distinct, with prominent eyes and long, pointed jaws. The legs are long and slender, evidently fitted for running. The body in general, especially the under side, has more or less metallic lustre.

These tiger beetles live upon the other insects, especially

caterpillars. By keeping some of them in a glass jar and furnishing them with cutworms or cabbage worms you may be able to see how they feed upon their prey.




GIANT WATER-BUG. A TIGER BEETLE.

The tiger beetles may best be observed out of doors, in cool weather, when they are less active than on hot days. On a cool day in April I have caught them easily even without a net, but on a hot day they are very quick and active. You will notice that when they alight they are generally facing you, a useful precaution against enemies.

THE YOUNG OF TIGER BEETLES.

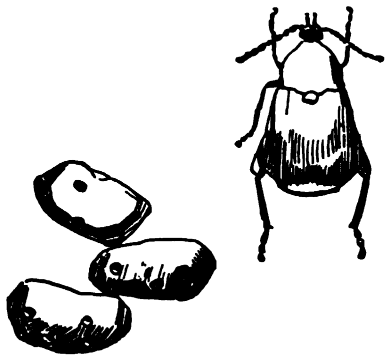
Throughout most of the season you may see along the roadsides, in pathways and gardens, small round holes in the ground, about half the diameter of a lead pencil. If you dig out one of these holes carefully you will probably find in it a very peculiar larva. It has a flat head, with large jaws. Its middle legs are turned back over the

body, on the back of which there is a strange-looking hump.

This is the larval form of the tiger beetle. It lies in wait at the mouth of its burrow for any insect that may chance to pass by. If a cutworm or other caterpillar crawls over the burrow, the opening of which is closed by the flattened head of the tiger larva, it is seized and dragged into the hole, where it forms a succulent meal for the occupant.

THE BEAN WEEVIL.

Another great group of beetles is illustrated by the bean weevil, shown natural size and magnified in the picture



THE BEAN WEEVIL.

herewith. In the field these weevils deposit eggs inside the green pods in small clusters. In a short time the eggs hatch into tiny grubs that feed within the beans, maturing in about a month. These insects are also able

to develop in dried beans, so that when they are present in beans put away in autumn many more may be present the following season. The best way of preventing such a continuance of their injury seems to be to inclose the infested beans in a tight vessel in which a little bisulphide of carbon, benzine, or gasoline has been placed. The fumes of these volatile substances will destroy the beetles. Of course, care must be taken that no fire comes in the vicinity of the treatment.

THE FIREFLY BEETLES.

In many respects no beetles are more remarkable than the fireflies—the creatures which so vividly illumine the evening landscape during July and August. As is the case with phosphorescent animals generally, the most remarkable fireflies are found in tropical regions. Every one has heard of the fireflies which in the West Indies are kept in gauze cages on account of their brilliancy.

X. *AMERICAN NUT GATHERERS.*

By F. Schuyler Mathews.

If there is any question about who is "boss" of the forest in summer and autumn, I think that question will be promptly and emphatically answered by the red squirrel or chickaree (*Sciurus hudsonicus hudsonicus*),[1] who claims the whole country, regardless of the limitations of the woods. Whether or not he is able to sustain his claim is another consideration which is less interesting to us; we are peremptorily ordered to "move on" by the highly agitated boss, that is certain, if animal language is capable of any interpretation. So we may as well consider the chattering red squirrel king of the forest; there is no harm in that. But is he? Yes, in a great measure he is. Mice and birds he terrorises, chipmunks he fights and chases away, and even the big gray squirrel he does not allow to live in his vicinity. A butternut tree in early autumn he considers exclusively his own, and it is the object of endless bickerings if any other creature attempts to approach it.

One can always tell the red squirrel in summer by his

[1] The nomenclature of this and all the other species is that of Mr. Outram Bangs of Boston.

nearly even rusty red colour. A broad, blackish stripe along his side separates this rufous colour from the buff-white tint of his under parts. He is not found south of southern New Hampshire and the northern peninsula of Michigan; south of that line is another similar species called *Sciurus hudsonicus loquax*, which is a trifle larger,

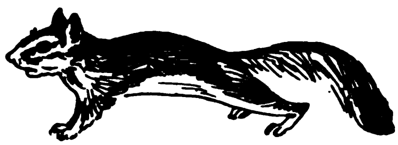
RED SQUIRREL.

redder over the middle of the back, and decidedly grayer beneath. This last squirrel is very abundant through the middle part of his range, which would extend from Connecticut to southern Minnesota; the southern limit is Virginia.

The red squirrel is particularly fond of the seeds of coniferous trees, and he has a special penchant for the butternut, which he pierces at one side, and, through a hole not over half an inch wide, he succeeds in extracting all the meat. Beechnuts and corn he likes to store away for the winter months, of course, but he will leave both to the mice and chipmunks if he can collect all the butternuts

he wants, which would be a couple of bushels, more or less.

In the same locality with the red squirrel we will find the pretty little striped chipmunk (*Tamias striatus*), whose highway is the stone wall. This little fellow has three white stripes marking his tawny back, each one of which is bordered with black. His tail is an insignificant affair, and his ability to climb is strictly limited; even if he does ascend a tree for some distance, he becomes confused at the slightest disturbance below, and not infrequently falls



THE RED SQUIRREL CHATTERING.

to the ground. He and the red squirrel do not get on well together, and they avoid each other as much as possible. If the meeting does occur the chipmunk gets the worst of it and usually retreats in hot haste. So tame is the little creature that he considers my summer home part of his domain and visits studio or kitchen—whichever promises the most edibles—with cool indifference regarding the company. He has a remarkable habit of stuffing his cheek pouches full of bread crumbs or cake, until he looks as if he were suffering from a severe attack of mumps. Sunflower seeds he is particularly fond of, and the seeds of sheep sorrel and hardhack he does not despise. Rarely I find him with a stray nut, but I sus-

GRAY SQUIRRELS IN THE WOODS.

From photographs by A. R. Dugmore.

pect that, beyond beechnuts, such hard-shelled fare is not quite to his taste. The nest of the chipmunk is in the ground about eighteen inches below the surface; it is reached by a tunnel about two feet long. In late October, when the nights grow frosty, he retires for the winter, and rarely pokes his nose out of doors again until the following April. He stores away an abundance of beech-

THE CHIPMUNK.

nuts, seeds, corn, oats, buckwheat, and old bread crusts, and lives in plenty through the season of ice and snow. But the red squirrel wanders abroad even in the coldest weather, and, not quite as provident as his relative of the striped coat, turns up frequently in the snowy farmyard to glean what is left after feeding the animals. He is somewhat of a thief, too, and robs the mice of the store of grain which they have snugly tucked away in some decayed tree stump. However much he may have stored away for his own use, he is evidently not averse to stealing from his neighbours, and as a consequence the farmer has to guard the four posts of his corn barn with slippery

tin to prevent his depredations. If some of the kernels of corn are closely examined which the squirrel or the mouse has cast aside it will be found that the portion near the base of the kernel is quite scooped out clean. It is the tender germ which is gone; the little animals know where to find the best of everything!

Undoubtedly the best nut gatherer of our northern woods is the gray squirrel (*Sciurus carolinensis leucotis*). He is equally fond of the walnut, hickorynut, butternut,

THE BLACK SQUIRREL.

pignut, beechnut, and hazelnut. His habitat is naturally the hardwood forest, where the chestnut, oak, and hickory abound. In this respect he differs from the red squirrel, who frequents the evergreen forests, and whose special liking is the seed of the spruce and pine. The typical colour of the gray squirrel is a rusty-tinged silver-gray, with under parts white. The so-called black squirrel is not another species—his dark colour is simply a case of melanism. Melanosis or melanism means becoming black. It frequently happens that large numbers of the black squirrel are found in one locality, but this is simply an accidental condition of squirrel life, for it will very

likely be discovered, upon investigation, that all degrees of colour between black and gray also exist in this same locality.

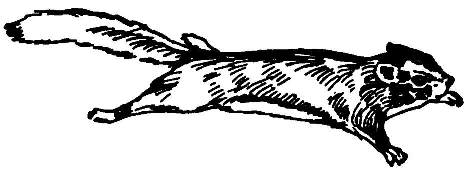
THE NORTHERN GRAY SQUIRREL.

The gray squirrel is remarkably graceful in all his movements. It seems as though some subtle curve was always produced by the line of the back and tail at every light bound of the athletic little creature. He never moves abruptly or jerks himself impatiently, as the red squirrel is continually doing. On the contrary, all his movements are measured and deliberate, but swift and sure. He never makes a bungling leap, and his course is marked by a number of sinuous curves almost equal to those of a snake. He is here one minute, and the next he has slipped away almost beyond the ability of our eyes to follow. The northern gray squirrel is common from

the Alleghanies of Pennsylvania north through New York and New England to southern Canada and west to Minnesota. Below that line his place is taken by another

THE FLYING SQUIRREL.

species, called the southern gray squirrel (*Sciurus carolinensis*). The difference in the colours of the two species is distinctly but not conspicuously marked. The southern squirrel is dark-yellowish rust-colour above, marked upon the side with gray and black-tipped hairs which give a grayer tone to these parts; beneath the colour is white. This species is found in the southern Hudson River valley



A LONG LEAP.

and west through the Alleghanies south of Pennsylvania to Indiana and Missouri.

The beautiful little soft-eyed creature called the flying squirrel (*Sciuropterus volans volans*) is a nocturnal animal that begins to stir himself late in the afternoon. About the time the yellowbird is dipping along the sky, chirruping as he goes, the flying squirrel leaves his nest and begins a series of aërial leaps from the treetops. The sun

HICKORY NUT BORED BY RED SQUIRREL.

BUTTERNUT BORED BY RED SQUIRREL.

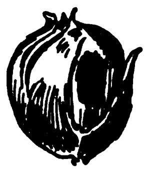
has already set and most of the birds have retired to their nests, but this squirrel is in for a frolic; watch him ever so closely and it is impossible to think he is a creature without wings; the leap is twenty, thirty—ay, forty feet! And no bat could cover the space more noiselessly.

The soft, silky fur of this squirrel is brownish gray, and underneath he is a delicate yellowish white. His skin fits loosely, and when he stretches out an arm it reminds one of a bishop's sleeve. In springing from branch to branch

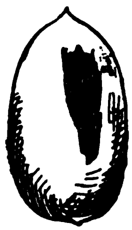
he flattens himself and slides through the air with the rapidity of a bird on the wing. He is rightly called the flying squirrel. It is said that on occasions he will drop through the air a distance of one hundred and fifty feet.

The flying squirrel lives almost exclusively upon nuts; pecans, hickories, and hazelnuts, I think, he fancies most of all. He makes a capital pet, and thinks a pocket was especially designed for his comfort; but if he is rudely disturbed he is inclined to nip one's fingers.

Of all our nut trees the hickory and chestnut afford the best opportunities for a study of the habits of squirrels. An opera glass is quite necessary for close observation,



Pignut Bored by Squirrel.



Pecan Bored by Squirrel.

and by its aid one may discover a thousand little details in the movements of the nut gatherers which otherwise would escape notice, and many of the animal's ways will prove as amusing as they are interesting. Watch the red squirrel handle a butternut; he does not gnaw away at it in any random fashion. No, he turns it over and over until he has sounded its depth of shell, and after he is through with it, if we pick it up, we shall find that the thinnest part has been penetrated. Squirrels have a

faculty for labour-saving. The hickorynut is always bored on the flat side, the butternut at a point where the meat of each half is easily reached, and the smallness of the hole in the hazelnut is astonishing in view of the fact that the kernel has disappeared.

I think Emerson was wrong when he made the squirrel remark that the mountain could not crack a nut—he really meant a man, not a mountain. The squirrel works scientifically, and in a minute pierces the nut with about three hundred and seventy scratches of his teeth and cleans it out. We pick up an apparently good nut and are completely deceived; the work of the nut-cracker is so perfect that we had not discovered the opening. If we had cracked the nut—well, everyone knows how it would have been smashed, so I will say no more.

POPULAR LECTURES IN PHYSICAL SCIENCE.

POPULAR LECTURES IN PHYSICAL SCIENCE.

I. THE GLACIAL EPOCH.

BY SAMUEL CALVIN, A.M., Ph.D.

WHAT THE NAME IMPLIES.

THE records of the glacial epoch furnish one of the unique chapters in geological history. The epoch derives its name from the fact that during its progress sheets of ice gathered in great force over certain portions of the earth's surface, which for the time being were special centres of accumulation, and, spreading thence by the natural laws of ice movement, eventually covered extensive areas, particularly in northwestern Europe and northeastern North America. The ice had its origin in snows which annually fell and piled up in excess of the amount annually melted until the mass reached a thickness of hundreds or even thousands of feet. Partly by pressure of superincumbent portions of the mass, and partly by freezing of water in the spaces among the snowy crystals,

the main body of all large accumulations of snow invariably becomes compacted into solid, transparent ice. Now, ice is not the brittle, inert thing that many suppose. In large masses, at all events, it behaves as a plastic or partially fluid substance. Slowly and resistlessly it creeps out over the surface, away from the centres of greatest accumulation, with a movement that can only be described as flowing. And so the great bodies of ice that formed during the glacial epoch were in motion and actually flowed out in radiating streams, or as continuous ice-floods or sheets, from centres where the excess of the annual snowfall over the annual waste was greatest. The length of the radius over which the ice streams flowed from their principal sources was in some cases seven hundred miles. Ice floods carried detritus from Norway to Great Britain. The region from Hudson Bay to the Ohio River was practically one great southward-moving sheet of ice, and icy desolation spread its unbroken continuity from central Nebraska to the Atlantic Ocean. Streams of ice having their sources in perennial accumulations of snow are called glaciers, and the prevalence of majestic glaciers down to the middle latitudes of both continents justifies the usage of calling this particular portion of geological time the glacial epoch.

TIME RELATIONS OF THE GLACIAL EPOCH.

That some portions of the earth's surface have suffered extensive glaciation at widely different epochs of geological time recent researches in world-history leave no room to doubt; but the glacial epoch, as the term is usually

SIDEWAYS VIEW OF THE MUIR GLACIER, ALASKA.

From a photograph by Rau.

accepted and applied, is one of comparatively recent date. What is known in geology as the recent epoch—the time since the inauguration of present climatic conditions; the time since the introduction and establishment of the modern types of animals and plants; the time since man became lord and master of created things—represents the to-day of geologic time. The glacial epoch we are here considering was yesterday; and so the records of this epoch furnish not only a unique but a recent chapter in geological history. Reasoning from the best data available, some have been led to the conclusion that from seven thousand to ten thousand years may cover the whole period since the retreat of the last great ice sheet from the northern part of the United States. The geological yesterday, from the beginning to the end of the great ice invasions which gave character to the glacial epoch, was many times—probably twenty to fifty times—as long.

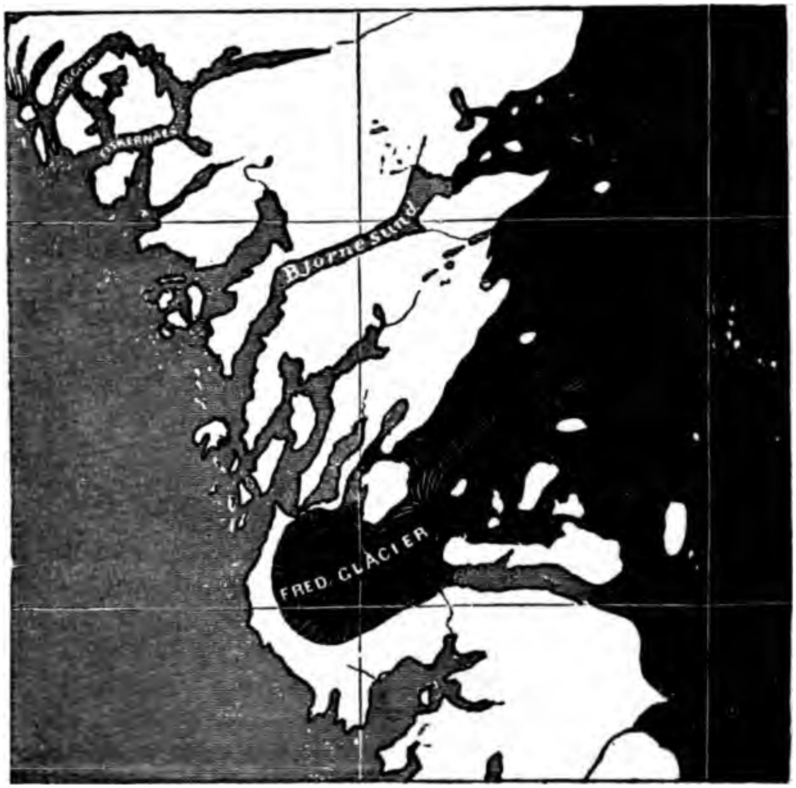
CONDITIONS OF THE GLACIAL EPOCH COMPARED WITH THOSE OF THE TERTIARY.

The glacial epoch, with its arctic climate and stupendous accumulations of snow and ice, was preceded by the epochs of the tertiary. During the tertiary, tropical or semi-tropical conditions prevailed over all parts of the United States and northward almost to the arctic circle. The climate, too, was moist, and the regions now occupied by the arid plains of the Dakotas and Montana supported luxuriant forests similar to the forests of the present gulf border from Louisiana to Florida. With the change from

tertiary to pleistocene conditions the tropical warmth came to an end over the middle and higher latitudes. The forests of cypress, magnolia, sassafras, sweet-gum and other southern types of trees gradually gave place to spruces and larches characteristic of the north. Progressive refrigeration finally caused even the spruces and larches, in the moister part of the continent, to be buried under beds of snow and ice which extended as far south as the latitude of St. Louis.

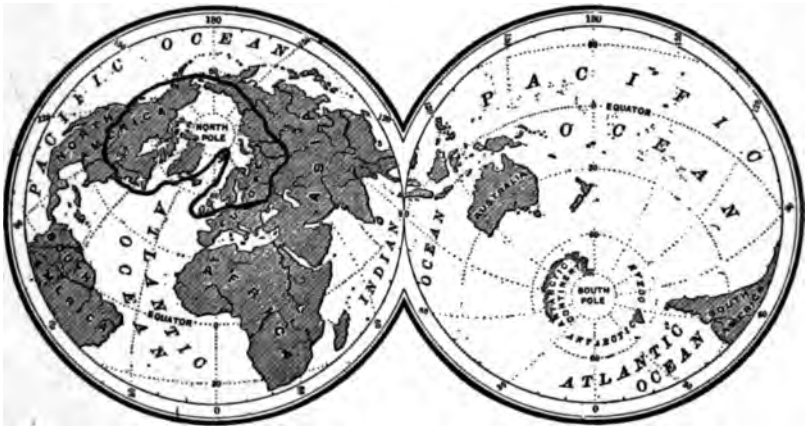
EXAMPLES OF MODERN GLACIERS.

In geology the present furnishes the key to the past. The correct interpretation of geological phenomena is possible only to him who is familiar with the agents and processes whereby effects are wrought to-day. The glacial epoch, therefore, is intelligible only to the student of modern glaciers. The Alps furnish typical examples of glaciers gathering on mountain heights, in the very presence of the observer, and flowing down the mountain valleys until they reach a point at which the ice is melted. All the glaciers of the Alps, however, are terminated by complete melting at altitudes between 3,000 and 4,000 feet above the sea. On the mountains of Alaska there are numerous glaciers that come down almost or quite to sea level. Some indeed reach the sea, push out for some distance along the bottom and are wasted, not by melting, but by the breaking from the ice front of large masses which are floated off as icebergs. All these glaciers have their sources in reservoirs of ice fed by precipitation from



Map of Frederikshaal Glacier, Greenland.
(The black part ice ; white, land ; shaded, water.)

the clouds that continually hover over the great snow fields of the higher altitudes. In Greenland and on the lands adjacent glaciers occupying thousands of square miles have their sources on surfaces that rise but little above the level of the sea. The ice streams here flow over the low coast plains and out upon surfaces lying beneath



MAP SHOWING GLACIATED AREA SURROUNDING NORTH POLE.

the sea; and icebergs in large numbers and of royal proportions are constantly shed from the free margins. In the Antarctic there are glaciers of continental extent, developed to a thickness unparalleled elsewhere in recent times, grinding out over the sea bottom to unknown distances and shedding into that wintry southern sea icebergs of such size as to make the largest floated off from the Greenland area insignificant by comparison.

FOOTPRINTS OF EXTINCT GLACIERS.

Before accepting a fact so startling, so marvellous, so contrary to all expectation and experience, the layman in science may well ask how it is known that ponderous sheets of ice flowed down from British America over Minnesota and Iowa and half way across Missouri? How is it known that Wisconsin and Illinois, Michigan, Indiana, and Ohio and all the States eastward to the New England coast were buried under a mantle of ice and subjected to all the dreary and frigid desolation which now obtains in central Greenland or in the inaccessible Antarctic? The ice of the glacial epoch has long since vanished from the greater part of the area it once occupied. Unnumbered glaciers not connected with the general ice floods of the epoch have likewise vanished, have become extinct. But wherever true glacier ice has flowed there are left unmistakable traces whereby its former presence may at once be recognised. A body of ice hundreds or thousands of feet in thickness, flowing, however slowly, over the surface of the land, produces permanent and characteristic effects. The native rocks of the region are crushed and worn on a gigantic scale. The inequalities of the surface are planed away. The underlying rock surface is polished and cut, as with a gigantic moulding-plane, into parallel ridges and furrows. Fragments of loose rock, caught in the lower surface of the ice, serve as the tools to carve and score the native ledges, and at the same time they are themselves planed to a true face which is marked with distinctive parallel scratches. Glaciers transport

and redistribute, hundreds of miles, it may be, from the original sources, all grades of loose materials, from finest silt or clay to boulders a score or more of feet in diameter. In the case of extinct glaciers of large extent the transported materials are left, where the ice melted, in an unassorted mass, which may take the form of an irregularly heaped up ridge coinciding in position and direction with the terminal margin of the ice, or it may take the form of a broad sheet covering the surface from which the ice gradually retreated by progressive melting.

Now within the limits of the States mentioned, and northward indefinitely through Canada, the loose surface materials are simply a heterogeneous assemblage of boulders, cobbles, pebbles, sand, and finest clay promiscuously mixed. The boulders and all other rock fragments of sufficient size to be recognisable are as a rule of kinds not native to the region in which they lie. They have come from the north, transported over hundreds of miles from native outcrops that may now, in some instances, be definitely determined. In very many cases the transported rocks bear clearest evidence of glacial planing, and the underlying native ledges are planed and scored in unmistakable fashion. Here are footprints of glaciers on a stupendous scale. That the area in question has been submerged beneath a sea of ice thousands of feet in depth becomes evident to any competent observer.

WORK ACCOMPLISHED BY THE ICE OF THE GLACIAL EPOCH.

The ice of the glacial epoch, like all other glacial ice, performed geological work on a scale proportioned in some degree to the thickness of the glaciers, their duration in time and the area of the region upon which they operated. The work of such ice is largely mechanical. Three processes are involved—destructive, translative, and constructive. The destructive effects wrought within the limits of glaciation during the glacial epoch need only be mentioned. The ice was certainly, in some instances, thousands of feet in thickness. It flowed for distances varying from ten to six hundred or seven hundred miles. In North America alone it covered half the continent. The volume of rock material that was crushed and ground and reduced to finest rock flour exceeds computation. The glaciers of this epoch were effective agents of transportation. An immense volume of loose detritus was carried forward in various ways by the ice, to be deposited scores or hundreds of miles from the initial point of its tediously slow journey. Preglacial valleys three hundred or four hundred or five hundred feet in depth were filled with glacial debris, and extensive plains are now found buried under similar material to a depth of scores of feet. The size of the fragments seems not to have affected either the rate or the ease of the translative process, for boulders of crystalline rocks from far to the northward, thirty feet in diameter, lie on the plains of northeastern Iowa along with pebbles and sand and clay, presumably from the same region.

ICE INVASIONS DURING THE GLACIAL EPOCH.

Science is indebted to representatives of the United States geological survey for the first clear evidence that in America this epoch embraced a number of alternating

GLACIAL PLANING OF LOWER CARBONIFEROUS LIMESTONE NEAR KINGSTON, IOWA.

stages of glaciation and deglaciation. The work of the national survey has been corroborated and supplemented by a number of other geologists. The record seems to be clearer and freer from complications in the Mississippi valley than elsewhere, and hence it is that the drift of Iowa, Wisconsin, and Illinois is now known to be a com-

plex assemblage of superposed, imbricating, overlapping sheets of till, bearing evidence of having been deposited at widely separated intervals of time. Five distinct drift sheets are discriminated, which, beginning with the oldest, are known respectively as pre-Kansan, Kansan, Illinoisan, Iowan, and Wisconsin. The pre-Kansan glaciers, which overran Iowa and northern Missouri, had their origin in a great centre of distribution west of Hudson Bay. From this centre they flowed with slow, creeping motion until an area large enough to embrace empires was buried under a sea of ice. How long the glacial conditions of this first recognised ice invasion persisted cannot be determined, but the time would be measured in stately moving centuries. At length, however, the climate became less rigorous, the ice slowly melted, the terminal margin retreated northward, and there was left, spread over the abandoned plains, a sheet of loose rubbish —drift, till—embracing all the varying sorts and sizes of rock debris which the ice had gathered and carried forward during its period of advance and culmination. Such was the genesis of the pre-Kansan drift.

The retreat of this first ice of the glacial epoch was followed by a time of mild climate, the Aftonian interglacial age, during which forests took possession of the land, soils were developed on the surface of the drift, and peat beds were formed in the marshes. The length of the Aftonian cannot be expressed in years. Its relative length is inferred from the extent of the changes wrought in the surface before the next ice invasion. The old drift was profoundly modified, and certain river valleys are known to have been excavated during the Aftonian time.

The Aftonian was brought to a close by a second depression of temperature, by a second accumulation and advance of ice, by the oncoming of the Kansan stage. There are reasons for believing that in Kansan time glaciation was more general than during the pre-Kansan. Glaciers radiated from at least two centres, one west and one southeast of Hudson Bay. Other subordinate centres there may have been, but as yet they have not all been definitely located.

GRANITE BOULDERS ON IOWA DRIFT-PLAIN NEAR WINTHROP, IOWA.

The Kansan ice at length disappeared by slow, gradual melting. The Kansan drift was left exposed to the atmosphere. Climatic conditions once more favoured the growth of forests, the accumulation of peat, the development of soils. The interglacial stage following the retreat of the Kansan ice is the Yarmouth of Leverett. During the Yarmouth interval the surface of the Kansan drift was deeply carved and trenched by drainage waters. The upper zone of the drift was changed by oxidation from blue to yellow or brown or deep red, and many of the boulders, within the zone affected by the weather, were

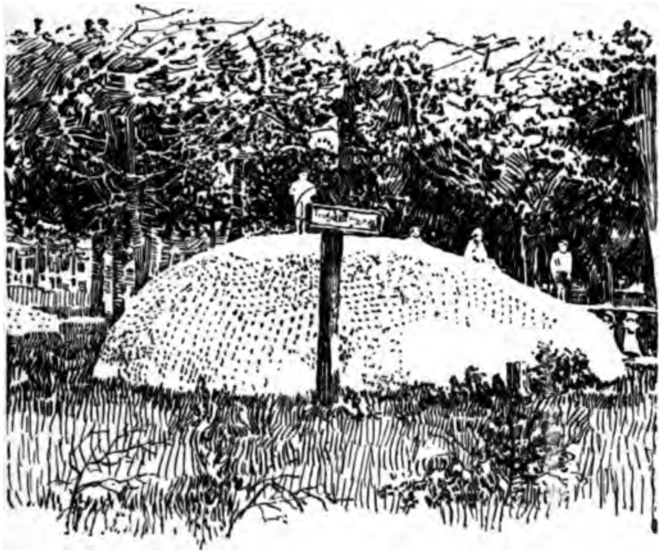
rotted and decayed to such an extent that they crumbled into sand. Measured by the effects produced, the Yarmouth interval was much longer than the Aftonian.

A third glacial age, known as the Illinoisan, followed the Yarmouth interval. The region southeast of Hudson Bay became again a centre of precipitation of snow, a centre of accumulation of ice. Glaciers radiating from this centre took possession of a large part of the continent, and one portion of the ice mantle spread into Illinois, and even crossed the Mississippi into southeastern Iowa. The corresponding extension of ice from the gathering grounds west of Hudson Bay has not yet been traced. In Illinois and southeastern Iowa the Illinoisan drift overlaps the Kansan and so brings comparatively young and fresh till in direct contact with the soil band, the peat beds, and the deeply weathered zone developed during the Yarmouth interval. Judging from the effects of weathering shown by the underlying Kansan, the interval between the two ice invasions represented by these till sheets was greater than the whole time from the retreat of the Illinoisan ice to the present moment.

The Illinoisan invasion was followed by an interglacial stage, which Leverett has called the Sangamon. The usual events which follow deglaciation—namely, rehabilitation of the land with forests, soilmaking over the freshly exposed drift, peat accumulation in low, marshy places and oxidation and weathering of the entire surface of depths proportioned in some measure to the length of the exposure—took place during the Sangamon interval.

The Sangamon interval, long when compared with recent time, came to a close with the invasion of the middle

latitudes by a fourth ice-sheet, the Iowan. During the Iowan interval ice gathered both east and west of Hudson Bay and spread outward in radiating currents from both centres of accumulation. Glaciation was much less



GRANITE BOULDER IN IOWAN DRIFT.

general than during the Kansan, and in many instances its extreme margin fell some hundreds of miles short of the maximum limits attained by glaciers of the Kansan stage. Only a small, irregular lobe, pushing out from the main body of the Iowan ice, reached as far south as the State of Iowa. This lobe overran what is now the northeastern counties, but less than a fourth of the State was covered, even when the glaciers of this stage were at

their maximum. On the other hand, the whole of Iowa, excepting a small corner belonging to the driftless area, the eastern half of Nebraska, the northern half of Missouri, and the northeast corner of Kansas, together with the entire glaciated area east of the Mississippi, were all simultaneously buried under the Kansan ice sheet, which extended from its extreme southern limit northward to the Arctic Sea. The western ice of the Iowan stage carried granite boulders in countless numbers and of large size. Not a few of the ponderous granites are from twenty to thirty feet in diameter, and, standing on the surface of the drift, they constitute characteristic and striking features of the prairie landscapes inside the Iowan border. Compared with the Illinoisan, the Iowan drift is young; much more is it young when compared with the remote Kansan and the remoter pre-Kansan till.

A short interval of deglaciation after the disappearance of the Iowan ice—the Peorian interglacial interval of Leverett—is succeeded by a fifth advance of ice from the north. The fifth glacial stage is the Wisconsin. The line marking the edge of the Wisconsin glaciers when they attained their greatest southward extension is very irregular and sinuous. In some cases these glaciers fell short of the limit reached by the Iowan; in some places they extended beyond it. A long lobe of Wisconsin ice covered the north central part of Iowa and reached down to Des Moines. At its southern extremity the drift of the Des Moines lobe rests on Kansan till. Near Peoria, Illinois, drift of this age lies directly on the Illinoisan. In western Cerro Gordo and Franklin Counties, Iowa,

it overlaps the Iowan. The margin of the Wisconsin area is characterised by very conspicuous moraines, which occupy a belt varying from two or three, to ten miles in width, and the irregularly heaped and tumbled piles of glacial detritus range up to one hundred and fifty feet in height. Recessional moraines, marking successive halts or slight readvances during the time of melting, are among the distinguishing characteristics of the Wisconsin drift.

The sand and gravel trains marking the courses of loaded streams, or the beach and delta deposits which record the presence of the glacial lakes, have not yet, in every instance, been severally referred to their appropriate stages of the glacial epoch. Little by little, however, the true history of this, the most remarkable epoch of geological time, is being deciphered, and the events connected with all its strange moods and variations are, one by one, being set in their proper places in the chronological sequence. And so, judging from the rate at which progress has been making during the last decade, it is but a question of a few years until the events of the glacial epoch will be as well known in their relations and sequence as the events of any epoch of historic time. In seeking a cause for the climatic conditions which made the glacial epoch possible, students of geology have been less fortunate than they have been in deciphering its history. Many ingenious and attractive hypotheses have been offered, but none as yet will bear the test of rigid examination. The glacial epoch, with all the severe and dreary conditions implied by the presence of continental glaciers down to middle latitudes, was a fact; but it is

Front View of the Davidson Glacier, Alaska.

too early yet to attempt explanations of the causes which led to the successive ice invasions.

The divisions of the glacial series recognised by the glacial division of the United States Geological Survey may be summarised as follows:

9—Fifth glacial stage, Wisconsin.
8—Fourth interglacial stage, Peorian.
7—Fourth glacial stage, Iowan.
6—Third interglacial stage, Sangamon.
5—Third glacial stage, Illinoisan.
4—Second interglacial stage, Yarmouth.
3—Second glacial stage, Kansan.
2—First interglacial stage, Aftonian.
1—First glacial stage, pre-Kansan or Albertan.

II. CHANGES OF THE EARTH'S SURFACE AND ANIMAL LIFE.

BY ALPHEUS SPRING PACKARD, M.D., Ph.D.

OUR earth is only less stable than the sea. Its crust or outer layers of rocks has from the earliest ages been repeatedly crumpled, folded, and either raised into vast plateaus over certain regions or depressed in other areas, there forming the bottom of the oceans. At the outset it is probable that the sea covered the whole globe, with here and there, especially in the northern hemisphere, islands destined to form the nuclei of the continents now rising above its surface. Since that early period there has been a constant struggle between the terrestrial and oceanic powers, but the land has steadily gained upon the sea. There have, however, locally been extensive and widespread invasions of the land by the sea, though upon the whole the present great oceans have from the earliest times been confined to their present basins. In the shallower portions, however, along the great coast lines, the changes of level have involved enormous extents of land and sea, the elevation of certain regions and the depression of others extending through thousands of feet.

It can therefore be well imagined what a profound influence these changes must have had on the animals

living both on land and in the sea. Changes such as these in the physical geography of the globe were evidently the primary factors in the modification and evolution of life forms.

Let us examine in some detail certain of the great geological changes and note the very probable effect they must have had on the origin not only of varieties and species but even of families and orders, as well as classes of animals. It is well known that the extinction of numerous important types of life was with little doubt due to widespread geological changes, such as the gradual upheaval of mountain chains, the ice period, and other climatic changes due to elevations and sinkings of land, and why may not the origin of the new forms succeeding them have been due to the same changes? We know that throughout geological history there have been progressive changes in the building up of the continents, and that throughout all time there has been a corresponding progressive development in life forms—a process of differentiation from the simple and generalised to the more complex or specialised, a gradual evolution from monad to man.

Our knowledge is very limited as to what took place between the time when our earth cooled down, assumed its present size and shape and became fitted for life, and the period known as the Cambrian, when the principal types of animals, with the exception of reptiles, birds, and beasts, had appeared. Indeed, we know almost nothing at all definite about it. But it will be readily seen that this was the most important and productive period in the life of our earth.

During this immensely long pre-Cambrian age, including the Laurentian and Algonkian periods of geologists, what extent of land existed was subjected to the most radical and widespread changes. We know little of them, as their effects have only been studied in limited spots near Lake Superior and elsewhere, but there must have been repeated revolutions. This is proved by the highly contorted and disturbed Archean (Laurentian) rocks, granites, and gneiss which have been observed at different points in North America, lying beneath the relatively less disturbed Algonkian series.

At a later time between the pre-Cambrian and Cambrian periods there was, according to Walcott, a great uplift and folding of strata; the elevated plateau thus formed, with its mountain ranges, extending perhaps for thousands of miles over the then continent, was carved into mountain peaks, while these were worn down by the rains, and the rivers cutting through them carried the debris into the sea.

One might think that the earth in these primeval times was too much disturbed and unfitted for the existence of life. But that plants and animals did exist is suggested by the occurrence of beds of graphite, which is altered coal, by deposits of iron and of marble in Algonkian rocks, themselves stratified, forming beds of sandstone, conglomerate, limestone, etc. Moreover, the Algonkian (Huronian) strata, besides containing abundant carbon and also coal gas, graphite, and rocks which will burn, have yielded fragments of sponges, shells, trilobites, etc., which shows that in pre-Cambrian times not only protozoans and sponges, but also corals, shelled worms

(*Lingula*), true worms, and trilobites had gained a foothold in the seas of that time. In short, in the hazy, dim, remote ages before the Cambrian period the biological forces had gained the victory, and the seas and even perhaps the land masses of those times were tenanted by comparatively highly organised life forms. Chaos and darkness had been succeeded by light and life, and the very changes and vicissitudes which were destructive to certain forms unable to adapt themselves to such adverse conditions were provocative of forms and types better adapted to such new conditions of existence.

And so it has been ever since those primeval ages, of which we really know so little. The earth's crust has again and again over extensive regions been rent and torn, portions thrust up above the sea, others cast down, whole plateaus and mountain chains have been formed, only to be worn down and erased, the roots of the mountains and fragments of fossiliferous strata being left here and there to tell the tale of creation and destruction, of rejuvenation and of senescence. One of the grandest results of modern geology is the history, now fairly well worked out, of the revolutions which have taken place in our own continent.

It should be borne in mind that these great changes, widespread and profound as they were, extended through long ages. There were immensely long periods of quiet preparation, during which there was a slow accumulation of beds at the ocean bottom, formed of material borne down to the sea by rivers rising in the highlands of the interior. These periods were succeeded by crises or periods of slow upheaval. Nature has taken her time for

all this work. The length of time which elapsed between the period when our planet became fitted for the existence of the simplest plants and animals and the Cambrian period of geologists has been estimated at from 35,000,000 to 40,000,000 years.

It is probable that these changes went on more rapidly than now, and that consequently the evolution of organic types was more rapidly accomplished and more thoroughgoing than in later times.

Sir William Thompson, now Lord Kelvin, insisted that "the world at a very early period was subjected to more rapid and violent changes in its physical conditions than those now occurring; and such changes would have tended to induce changes at a corresponding rate in the organisms which then existed."

We now pass on to a much later period in geological history—that of the Appalachian revolution, when the Appalachian mountains were formed, and there were corresponding changes throughout the globe. This was, from a biological point of view, the most notable event in the history of our earth, unless we except the appearance of man. In its effects on life, whether indirect or direct, it was of vast significance; for contemporaneous with and as a consequence of this revolution was the incoming of the new types of higher terrestrial vertebrates—those with limbs and lungs, such as salamanders and the like, with reptiles, birds, and beasts.

Since the Appalachian ranges were upheaved and carved by rivers into mountain peaks, at the close of what geologists call the paleozoic age, there have been great changes of level and physical geography over our Atlantic

coast region. The mountain region was worn down to almost a plain, with a broken surface like that of New England at present. Then the region was again upheaved and tilted up, and the rivers running more rapidly cut deep channels through the plateau, and mountains were thus formed. Several successive cycles of upheaval and wearing down have taken place from the close of the paleozoic era to the present day.

Now, all these changes in physical geography must have caused much variation in animal life. At the time when reptiles, birds, and beasts, or mammals, appeared, our Atlantic border presented different climatic zones; from tropical lowlands, with their vast swamps, to temperate uplands, stretching up, perhaps, to Alpine summits, with possibly glaciers of limited extent filling the upper parts of the mountain valleys. New Zealand at the present day has a subtropical belt of tree-ferns, while the mountains towering above have near their summits fields of ice and glaciers. In Mexico only about twenty degrees from the equator is the temperate plateau rising above the tropical belt, and farther up the sub-Alpine snow-clad peaks of Popocatepetl and Orizaba. So in the Appalachians of the paleozoic age, the cryptogamous forests and their animal life may have been confined to the coastal plains and lowlands, while on the higher, cooler levels may have existed a different assemblage of creatures.

Afterward these animals were wiped out of existence by subsequent changes, and new assemblages better adapted to the novel climatic and geographical conditions took their place. Besides the changes in the shape and

contour of the land, the extinction of certain forms was undoubtedly aided by the struggle for existence, or competition. Thus, during the age of reptiles these creatures dominated the earth and the sea. It took a long time for the birds and beasts, after certain lowly forms appeared, to gain a foothold. Competition drove the bird type to live in the air, and the mammals burrowed in the earth, lived in trees, or ran over plains less frequented by reptiles. At least, in a way not yet understood, the reptiles in part died out and were replaced by the more intelligent types of birds and mammals.

When we come to the ice period we readily see what a widespread influence a change of climate had on living beings. The extinctions and migrations which took place at the time man appeared are well known, and illustrate in a way every one can appreciate how profound and immediate geological changes have been in causing the origin of life forms.

III. THE FOSSIL WORLD AND HOW MAN CAME TO KNOW IT.

By Gilbert D. Harris, Ph.B.

There may be something slightly misleading in the title of this essay. I rather think there is. It perhaps suggests that the fossil world is a world, or at least a region by itself far away from the abode of man, to be reached by some "Wonderland" journey or trip with Jules Verne, or through an opening constructed *à la* Simmes into the very heart of the earth.

The story we have to offer is no such well-studied feast for the imaginative mind as these allusions would indicate; it is simply a cold collation of facts, served in the shade of one of the most recent offshoots of science.

The branch or offshoot of science here referred to is geology, and the facts relate to the extraordinary manner in which mankind in general has looked upon and, stranger still, continues to look upon fossil remains as they present themselves to view in this and in foreign lands.

Proctor has well said that it is a useless waste of time to search the archives of antiquity to try to discover the people who first took note of astronomical phenomena.

But it is not so difficult a task to ascertain the names of the men or people who first comprehended clearly the principles of astronomy. So it is in geology, the science so largely based on fossil remains. In Egypt, India, the Holy Land, Greece, Italy, and elsewhere in the Old World, as well as along the Atlantic, Gulf, and Pacific borders of our own country, or wherever marine rocks of comparatively recent origin occur, the fossils they bear are so plainly and abundantly displayed as to force themselves upon the attention of uncultured or even but semi-civilised people.

Long before the Christian era, Herodotus, Xenophanes, Aristotle, and others pointed out the occurrence of sea-shells high up on the flanks of the hills and at long distances from the sea. But it was many centuries after that era before the significance of fossils was well understood by a few of the brightest minds, and even now, in contradistinction to the general diffusion of astronomical principles, the vast majority of civilised man is in the same bewildered uncertainties regarding the meaning of the simplest geological phenomena as were the ancients centuries before Christ.

Let us here throw a few pictures on the screen of our imagination; pictures taken, by the way, from real life.

Leaning on a fence near a marl-pit or other excavation, natural or artificial, is a man of the last decade of the nineteenth century, who has been attracted from his house to that quarter of his plantation by a peculiar pounding or pecking more or less akin to the sound of the ditch-digger's pick as he loosens up the dirt beneath his feet.

He finds here not a ditch-digger, but a what? A man, young, to be sure, but old enough to know better, breaking off chunks of sandstone, clay, and marl here and there, splitting other fragments and rapidly scanning their contents, selecting this, rejecting that, all with such an air of seriousness that expressions of pity, ridicule, and wonder play by turns upon the bystander's countenance. Finally, unable to restrain mere curiosity any longer, and feeling the strength of his own position—being on his own plantation—he propounds the following questions: "Are you hunting for gold? Little shells or bones, did you say? Well, I declare! Do you reckon they ever were anything, ever really alive? Sea-shells, did you say? How do you suppose they ever got way off here? Don't you reckon they were left here in time of the flood?"

After spending at this locality all the time that the results seem to warrant, and having wrapped by itself in paper each choice shell like these (see Fig. 1) and others, and put them in his collecting sack, the geologist sets out for another exposure he has seen at a distance or has been referred to by some older worker in the same field. As he walks along the dusty, red road with his nadir-seeking burden on his back, his thoughts turn from the heat of the day to the song of the bird, and finally to the questions of the well-meaning but ill-informed new acquaintance. "Looking for gold?" a question very natural indeed, and quite germane to modern times. But the other questions, yes, even the very order in which they were put, bring to mind most vividly the headings of the great chapters in geological inquiry from the earliest

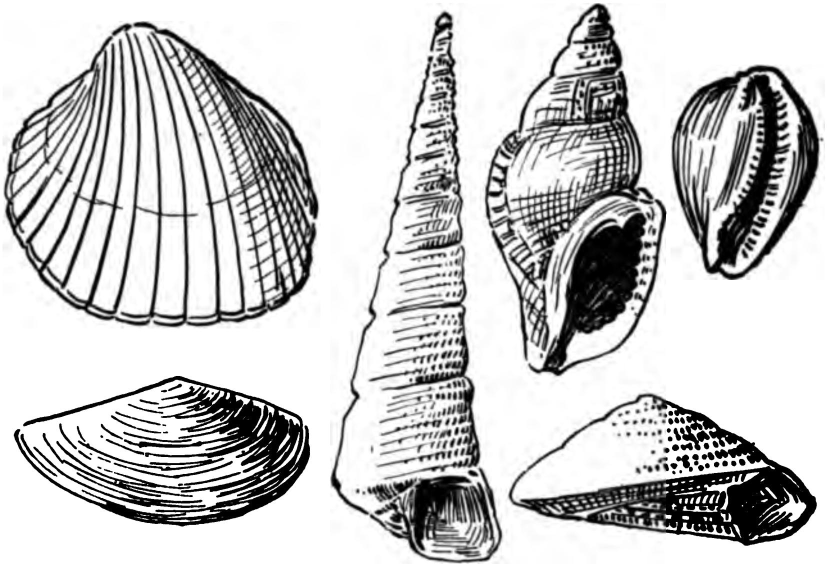


Fig. 1.—Fossil Mollusca from the Cenozoic (Eocene) Beds of Alabama.

known historic records to the close of the eighteenth century.

We now rap the floor with our wand as a signal to the man at the lantern to show us picture number two.

Here we see another young geologist pounding to pieces large fragments of rocks in a quarry in one of our northern States. You will notice on his face the same expression of eagerness and interest in examining every surface of each fragment opened up to his view by well-aimed blows from a heavy steel hammer.

He is soon espied, and the men in the adjoining field rest for a time on their hoe-handles and discuss the situation as follows: "He's hunting for gold," says number one. "No," rejoins a second, "he is one of those fellows who come from —— University looking after little shells in the rocks." "What little shells in the rocks? Nonsense, have you gone mad?" "Well, I don't know, but Sam Smith's boy was at the school awhile and that's what he called them when he was home last summer." "I never saw anything in those old stones," says a third, "but I do wish those fellows would carry them all away with them; it would save a lot of trouble, for when you do pick them up and draw them to a fence corner and dump them they make fine places for woodchucks to burrow and are regular hotbeds for weeds and briers." "But here's one of these stones now; see these little shells in it," exclaimed number two triumphantly. "Shells! No; unless you mean nut shells that have fallen from some of these trees and have petrified in that stone. Here's a hickory nut shell, here a basswood, and here a walnut, and there, that looks like a petrified butterfly; see his wings!"

"These things just happened to be shaped that way when the stone was created; that fellow over there is looking for a mine of some kind or other; he wouldn't work that way unless he was getting good pay for it, I tell you," said the first speaker. Then the dinner horn blew and the three field hands repaired to the house, where, after washing by turn in the tin basin on the steps and carefully parting their locks before the little cracked mirror tacked up by the kitchen door, they enter, and after blessings, take up the thread of neighbourhood news where it was dropped at breakfast time.

In the meantime the geologist takes out some paper from his collecting sack and proceeds to wrap up his finds.

Another rap on the floor brings a third picture to the screen.

Here you see a ditch is being dug for a sewer pipe from a nearby town through a swamp to a deep, slowly-flowing creek. In spite of the boss' command, "Work!" all hands are clustered about a skull of monstrous dimensions and strange appearance, discussing earnestly whether it ever did belong to a real, sure-enough, live man, or, if so, about what must have been his height. Other bones are found which are of easy identification—leg, finger, arm, bones, ribs, backbone, and all. Finally a doctor comes along and agrees to remove the troublesome bones free of charge and his offer is gladly accepted.

If time permitted we might rap for other slides, such, for example, as the one where the roots of coal plants are declared to be petrified rattlesnakes' rattles, eyes, scales —all "preserved perfectly and admitting no doubt as to

their identity," or the one in which the coralline fossil archimedes is known to be a fish's backbone; or the one that shows how septaria are generally regarded as petrified turtles; or the cast of the cockle-like cucullæa is believed to be a petrified turtle's head; but enough has been said to make the point clear we have in mind—*viz.*, to show how prone is mankind, even to-day, to interpret what he sees of the fossil world by the familiar object that

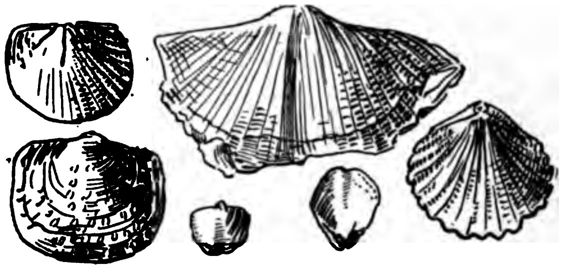


FIG. 2.—BRACHIOPODS FROM THE DEVONIAN (CHEMUNG) ROCKS OF NEW YORK.

surrounds him. Apparently it never occurs to him that the animals and plants of to-day, and, in fact, the very configuration of the earth's surface, are the results of an infinite amount of past changing. Yet without this idea there is to him no fossil world, no geology, any more than there are landscapes for the blind or melodies for the deaf.

Such being the general state of man's mind from the earliest historic times to the present, how came it that the true meaning of fossils was ever ascertained? Before explaining how, let reference be made to certain facts brought out by the foregoing illustrations. Note that

where fossils come from rocks belonging to comparatively recent geological periods (cenozoic) they bear a strong resemblance to living forms. See Fig. 1. And that those from very old rocks (paleozoic) bear less or sometimes even no resemblance to living forms. See Fig. 2. The latter, although truly marine invertebrates, have, as we have already seen, been even referred to as nuts of living trees.

Now it so happens that among the cenozoic fossils there are some which do not bear a strong resemblance to living forms. Again, in the paleozoic there are those occasionally that do resemble recent species. But in an intermediate age, the so-called mesozoic, there is a wonderful commingling of recent and extinct types of life. Such circumstances naturally lead the logical mind to conclude that in ages past there were forms of life somewhat different or even very different from any now seen on the face of the earth. In other words, the idea of the extinction of species, genera, families, and whole groups of living beings was too obvious to be overlooked by the more careful observers.

Gesner, a Swiss botanist, published in 1758 a treatise on fossils. He observed that in certain beds (cenozoic) the fossils resemble recent forms, while in another group of rocks (mesozoic) the fossils were of unknown types, and if now living at all they inhabit distant seas.

In 1790 William Smith, an English surveyor, published his "Tabular View of British Strata." He differentiated his "strata" by means of the organic remains they severally contained, and thus, whether fully comprehending the significance of fossils or not, brought them vividly to

the notice of the scientific world by showing their importance in practical field geology.

While this work was going on in England, Lamarck had been carefully studying, describing, and figuring the fossil shells from the Paris basin, and had referred many to living genera, though the species were for the most part distinct. Soon came the immortal works of Cuvier on the fossil vertebrates in the cenozoic rocks about Paris. Being a close student of comparative osteology, this author showed the affinities as well as the differences between the animals these bones once belonged to and those inhabiting the earth to-day.

At the beginning of the previous century the fossil world was well known to the few. Ever since that time new reports have appeared depicting its wonders. Let us then sincerely hope that before the close of the twentieth century the many may have grasped its salient features.

IV. EXTINCT MONSTERS.

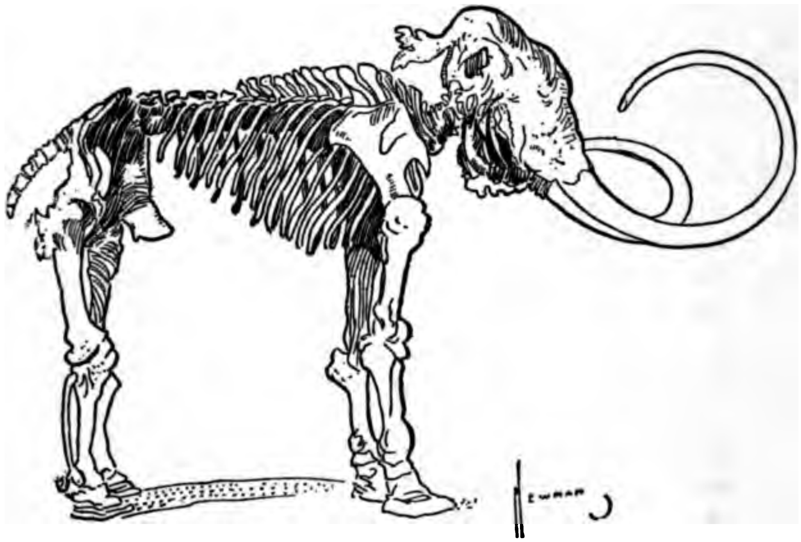
BY JAMES E. TALMAGE, Ph.D., F.R.S.E.

ASCENDING from the earliest of the rock strata to the deposits of the present time we find the fossilised remains of animals and plants imbedded and preserved, forming veritable pictures on the stony pages of earth's record—illustrations of the text, accurate and reliable, making plain to the attentive reader many matters connected with the ancient life systems of our globe.

Vertebrate remains of huge animals, principally those of fishes, are first encountered in the Devonian system of rocks, and the time represented by those deposits is known distinctively as the age of fishes. But the fishes of that day were widely different from the typical fishes of the present; these latter possess characteristic gill covers and true bony skeletons, while the Devonian fishes had cartilaginous skeletons, vertebrated tails and fins, which may be compared to articulated limbs.

The dinichthys (huge fish), from the Devonian rocks of Ohio, has been described by Professor Newberry as being at least eighteen to twenty feet in length and fully three feet in thickness. The "giant fish" is known to have measured six feet across the head, and to have possessed

an eye-orbit nine inches in circumference; it probably attained a length of thirty feet. Then, there are the "berry bone," the "bony scale," and the "winged fish," all possessing, in common with those before named, a protecting armour of closely fitting plates covering the head and forepart of the body.



THE MAMMOTH ELEPHANT.

But as time progressed fishes decreased in size and strength, and yielded their place of supremacy as rulers of the ocean to the "sea saurians," and these, with their congeners, the "land saurians" and the "winged saurians," were so numerous and characteristic as to give to the time represented by the mesozoic deposits in which their remains occur the distinguishing name, age of rep-

tiles. During the greater part of that age reptilian forms predominated among all vertebrates. Among the sea saurians the monstrous fish lizard claims attention. In some of its species this creature attained a length of forty feet. The animal possessed a comparatively short, thick body, suggesting in outline that of the dolphin; its head was heavy and large, its neck short and stout. Its eye socket, which measured three or four feet in circumference, was provided with a circlet of adjustable bony plates, apparently suited for adapting the eye to near or distant vision. Its limbs were huge paddles, and these, with the long tail, which in the light of recent discoveries is known to have been expanded at the tip, gave to the animal exceptional powers of rapid and vigorous movement in the water. One species recently described by Professor Marsh, from the deposits of Wyoming, was devoid of teeth and was provided with the exceptional number of six digits in each of its limbs.

Prominent among the saurians that lived on land was the iguanodon; it is so named from the marked resemblance between its tooth structure and that of a living reptile, the iguana. The iguanodon was herbivorous in habit; it reached a length of thirty feet and in weight exceeded that of a full-grown elephant. It must be classed as a bipedal creature, its hind limbs being developed far beyond the front pair, and serving, in conjunction with the enormous tail, as a tripod to support the colossal body when at rest.

The monstrous lizard was another bipedal land reptile of the Jurassic time. It was carnivorous, as is attested by its large, tiger-like teeth, and must have been a formi-

dable beast. A thigh-bone of this animal has been found measuring forty-two inches in length; the entire length of the creature could not have been less than thirty feet in the largest specimens.

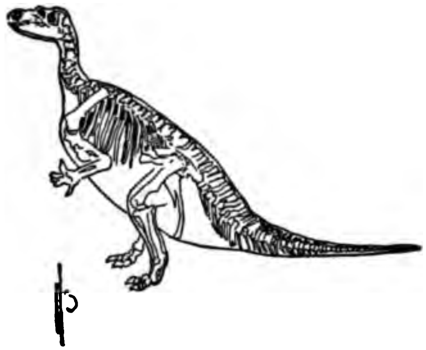
The roof lizards were even more remarkable in their general appearance. Rising from the ridge which marked the course of the animal's backbone was a succession of plates, broad at the base and diminishing upward, some

COLOSSAL SLOTH.

of them measuring three feet in height; toward the end of the tail these plates assumed the form of immense double spines. The use subserved by these strange appendages has not been ascertained.

The later Jurassic deposits of Colorado and Wyoming have yielded to the veteran paleontologists, Professors Marsh and Cope, a great variety of reptilian forms new to

science and from the abundant occurrence of a certain kind of reptile the strata have been called the Atlantosaur beds. The atlantosaur itself was one of the largest herbivorous reptiles known. It is shown to have been fully eighty feet in length, and a single thigh-bone has been found to be six feet long. The brontosaur left footprints in the mud each covering a square yard and the animal itself was at least sixty feet long. Its body was thick and



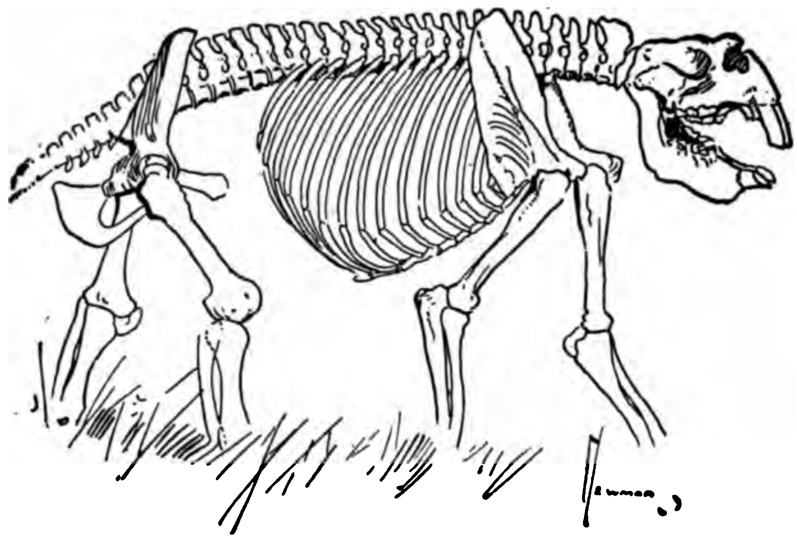
GIGANTIC DINOSAUR.

heavy terminating at one extremity in a long, tapering tail, and at the other in an equally slender neck with an insignificantly small head. Many of the land reptiles of that time show this diminutive type of head and a brain capacity even more disproportionately small. Nevertheless, the animals were not without brains. To compensate for the lack of nervous tissue in the cranium, there was a very great expansion of the spinal cord in the regions of the sacrum, forming a sort of sacral brain. As noted, the hind limbs of these animals were the most

highly developed parts of their anatomy, and the location of the largest accumulation of brain or nervous tissue in the immediate neighbourhood of the limbs would insure a more complete control of the muscles necessary to operate such mammoth appendages. It has been facetiously suggested that if the adage be true in general that after thoughts are the best, such a remark would be particularly applicable to these creatures who carried their brains in the posterior part of their bodies.

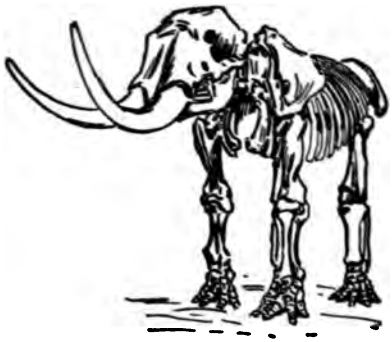
With the passing of the mesozoic age the reptiles became subordinate to the higher forms of vertebrate life—notably mammals and birds. From the tertiary beds of India have been taken the remains of numerous mammals, prominent among which is the dinotherium. This animal ranks among the largest of all known land mammals. Its skull, which measured three feet in length, shows a lower jaw curved downward and supporting a pair of enormous projecting teeth, like tusks. From the end of the tusks to the crown the skull measured five feet in height. The same deposits, as also others of more recent date, have furnished abundant remains of the mammoth and the mastodon.

Undoubtedly vast herds of mammoths roamed over the interior plains of Europe during the quaternary period, and their remains are now abundantly found, particularly in Siberia. The mammoth proper exceeded by one-third the height of the tallest existing elephant, and was probably twice as heavy. Teeth have been found weighing fourteen pounds each, and tusks have been known to go over four hundred pounds a pair. These tusks are collected and sold as ivory in the Russian markets. At the



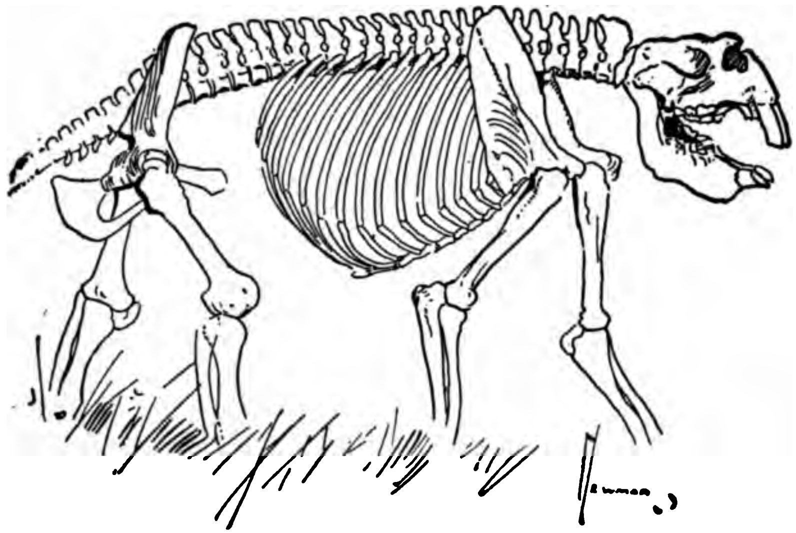
Gigantic Extinct Marsupial.

beginning of the past century an almost perfect carcass of the mammoth was freed by the melting of the ice at the mouth of the Lena River; the flesh was so well preserved that the dogs and wolves of the neighbourhood fed upon it. The skeleton is now in the Petrograd museum, with portions of the skin still attached. The animal was covered with a thick coat of long, shaggy hair.



MASTODON.

Mastodons were common to the quaternary day both in Europe and America. Teeth of this creature have been found weighing seventeen pounds apiece, and tusks from twelve to fourteen feet long. The American mastodon stood thirteen feet high, and from tusk-tip to tail measured twenty-five feet. Within the ribs of a specimen taken from a New Jersey bog were seven bushels of twigs; this item furnishes some indication as to the capacity of the animal's appetite. The megatherium surpassed the rhinoceros in size, though in structure and habit it must be classed with the sloths. It was particularly remark-



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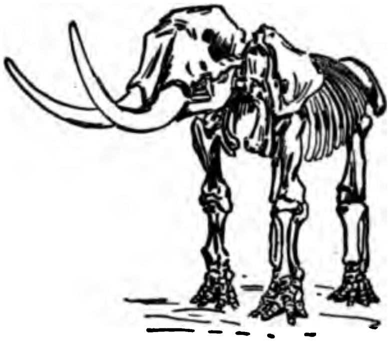

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able for the massiveness of its skeleton; indeed, its bones appear as if soldered together. It would seem that the creature was incapable of rapid motion, and probably such powers were unnecessary to its welfare. It was herbivorous and fed on the foliage of trees, which it was able to reach by supporting itself on its colossal hind limbs and tail while with its yard-long hands it drew down the leafy branches.

The glyptodon was a strange animal, clad in a huge shell like that of a modern turtle. The carapace was five feet long, and the entire length of the animal from tip of nose to tip of tail was fully nine feet. In bulk we may properly compare it with an ox.

The birds whose remains are found in the rocks were not less strange in their grotesque forms and enormous stature. Limb bones have been found as large as those of a horse, and toe bones equalling those of an elephant. The dodo, while not of great size, attracts attention by its clumsy appearance. It weighed probably fifty pounds and was covered with down and feathers; its wings were as useless for purposes of flight as are those of the ostrich. This bird is known to have existed until about two centuries ago.

And so passes the panorama of ancient life on earth, each dominant form flourishing for a season and then giving place to later and more modern types.

V. COLOUR IN NATURE.

By A. S. Packard, M.D., Ph.D.

We all admire the gay colours of flowers, birds, and butterflies. They attract our attention in early childhood, and afford an unending charm throughout life. Savages deck their bodies with gaudy blossoms and imitations of bright flowers, and the feathers of brilliantly coloured birds adorn the hats and bonnets of women in all classes of society. With little doubt the beautiful colours of flowers, shells, insects, and birds have made them the favourite subject of study by naturalists. Our most costly and luxurious works in botany and zoölogy are monographs on brightly coloured plants, butterflies, and birds, and these beautiful creatures have led many to the study of nature who would otherwise have been indifferent to the beauty of the living things around them.

It was not until Darwin, Wallace, and others began to speculate and philosophise on the uses to the animals themselves of these bright colours that the subject of colour in nature was taken up and the matter seriously discussed. We are even told by these naturalists that animals are protected by a certain style of colouration. When a moth or butterfly is assimilated in colour to the

flower or tree or other object on which it may rest, it escapes the notice of insectivorous birds. Hence insects owe their lives to the colour of their bodies or to the arrangement of the stripes or spots with which they are ornamented. Thus the zebra is so striped that herds of them running or turning rapidly about in the night are rendered practically invisible by their black stripes, so that they, in many cases, though of course not always, escape the attack of lions and other carnivora. Other animals do not so much wear a protective style of dress as one which serves to warn their enemies that they are malodorous or bad-tasting. The skunk is deep black, with conspicuous snow-white bands, rendering it distinctly visible in the darkest night, so that dogs and wildcats allow it to go scot free. Such a style of colouration is called "warning," as in such animals their very naked hues serve to warn off their natural enemies. The great majority of frogs are green, and multitudes are snapped up and swallowed by herons, fowl, and other birds. In Nicaragua, among many frogs of the ordinary style of colouration, there is one little species found about plantations which is brilliantly marked with red and blue lines and spots. It was observed that hens and ducks would not touch them, owing to their bad taste. So it is with many kinds of caterpillars; the most gayly marked ones are in general not eaten by birds, owing to their bad taste. The birds recognise and pass them by, do not waste their time on them, but eat immense numbers of plain green worms which are more palatable.

Thus it is that animals are protected by their style of colouration, or from mimicking or resembling other in-

sects which are distasteful, while vast numbers of species perhaps owe their very existence to their similarity in hue to the ground they live on, or to the peculiar colours or markings of the whole or parts of the leaves or flowers of their food plants.

It is even held by Wallace, Lubbock, and others that the forms and colours of flowers, especially the irregular ones, like beans and peas, are due to the visits of bees and other insects attracted to them by their colours.

This adaptation in colour to the ground they live on is well illustrated by the arctic animals, so many of which are white. It is thus with the polar bear, which is white throughout the year. Its white coat conceals it from the observations of the seals lying on floe ice, so that it can creep up to them unobserved. On the other hand, the arctic fox, hare, and ptarmigan, or at least the latter, harmonise in summer with the colour of the ground; but when winter approaches and the ground is covered with snow, they change to white. It is so with our common American hare or rabbit, which is white in the northern States where there is snow, but not farther south, where the snow does not lie long. Desert animals, insects, reptiles, birds, and many mammals are brown and dull in hue, exactly agreeing with the colour of the rocks and sands among which they live; so also on the light sand beaches of Cape Cod a species of locust is of the same faded-out tint.

As to the cause of protective mimicry, it is held by Wallace and other extreme Darwinians that all these cases of protective mimicry are due to natural selection

alone and to no other physical cause. This extreme view has been questioned, and there is at present considerable difference of opinion regarding the causes of adaptive colouration.

But before we discuss the hypothesis as to how and why colours are adaptive and protective, let us inquire how colours are produced in organic beings. It is, of course, most natural, in discussions as to the uses and final causes of this or that style of colouration, that the more philosophical and careful students should want to know just how colours originate and should then glean more facts bearing on the matter. When these subjects are fairly well worked out, we shall be in better condition to speculate as to the uses to the animal of this or that style of marking and as to its exact mode of operation.

At the outset it is most probable that owing to the general colours and arrangement of markings of this or that species of animal it is enabled to retain its hold on life. There are many species which differ chiefly in slight colourational features, whose whole existence is apparently dependent on such characters, so that of course the subject is one of prime importance. Colour in nature may be said to be one of the "burning questions" in modern biology.

The variety of colours in birds is almost endless. In a large number the colouring is protective, not only in the cases of the snowy owl and ptarmigan, but in those living in deserts and on our western plains. Nearly all the hen and partridge family, or the gallinaceous birds, harmonise in hue with the ground, and are thus in some degree protected from the attacks of hawks and eagles. In the

pheasants and birds of paradise only the females are thus protected, the brilliantly coloured males being also adorned with crests, plumes, or long tails of varied hues. Thus decked they are thought to attract the attention of the other sex. This is also the case with the males of certain spiders, which are both grotesque and gayly ornamented, and it has been proved by watching their antics that these colours and markings are "courtship colours." Another kind of marking is seen in the shore birds, such as plovers, which go in flocks. The bars and spots on their wings and tails, and which are fully exposed during flight, are "recognition marks," enabling stragglers to distinguish the members of their own flock from that of some other species, so that they may not stray too far or get lost.

The black, brown, red, orange, and yellow colours of feathers are due to the presence of pigments and are called absorption colours. "Blue, violet, and in some cases green, are produced by the light from a brown pigment becoming broken up as it passes through the superficial layer of the feathers in its passage to the eye; no blue or violet pigments occur in feathers, and green pigments are very rare." On the other hand, we are told that the beautiful metallic tints of many birds are entirely the result of structure, owing their existence to a thin, transparent, superficial layer, which acts as a prism. "In such feathers the colour changes according to the relative position of the bird and of the eye of the observer with regard to the source of light." White, and in some cases yellow, is produced by the total reflection of light from the spongy substance of the feather filled with air, like

white ice. There is no such thing as white pigment. (Parker and Hasnell's Zoölogy.)

In insects the conditions are somewhat different, as the colouring matter is lodged not only in the scales, but in the skin or crust of the body. The pigment in most insects, as well as in the lobster, is secreted in the deeper layer of the skin, under the cuticle, and this layer is called the hypodermis. When the lobster casts its shell, the soft hypodermal layer consists of cells which are filled with red and blue pigment masses. This cellular layer gives rise to the outer cuticle, which thus derives its hue, red and blue, from the deeper inner layer of colour-secreting cells. In most insects the cuticle is nearly colourless, or horn-coloured, or honey-yellowish, in tint.

In insects the colours are both optical and natural. Optical tints are due to the interference of light in scales containing no pigment, but which are marked with fine lines or are composed of two layers. The beautiful colours of butterflies reside in the scales, which themselves are usually seen to be colourless when examined under the microscope.

Natural colours in insects are both dermal and hypodermal. The hypodermal colours or pigments are formed from the waste products of the blood not thrown off with the urinary secretions. These colours tend to fade after death, but when inclosed and preserved in airtight sacs, such as the scales and hairs of butterflies and the wing covers of beetles, the colours remain bright for a longer time, though finally fading where dried specimens are exposed to the light. Hypodermal colours are lighter and brighter than dermal ones; they are light blue

and green of different shades, and yellow to orange, and numerous shades of these colours combined with white, the latter being due to the presence of air. (Hagen.)

The colours of insects can be changed by exposure to different acids; also by changes of temperature. Madder lake and indigo blue can be produced artificially by the action of acids on the fat bodies of insects. It has been found by experiments that pigments may be dissolved out by chemical reagents and subsequently restored by other agents. Both Coste and Urech have proved that red, yellow, brown, and black colours in the scales of certain butterflies are always due to pigments, and in a few cases greens, blues, violets, purples, and whites are due to the presence of pigments in the scales themselves. Mr. A. G. Mayer believes that the pigments of lepidopterous insects are derived from the blood of the chrysalis. The first colour to appear in the pupa or chrysalis of the American silkworm, on which he made his observations, is dull yellow ochre or drab; this is of the hue of the blood when removed from the chrysalis and exposed to the air.

Mayer has also artificially produced several kinds of pigments from the blood, which are similar in colour to various markings on the wings of the imago, or adult. He has also found that chemical reagents have the same effects on these manufactured products as on similar pigments in the wings of the living moth.

It appears from the careful researches of Hagen, Hopkins, Spuler, Urech, Mayer, and others that (1) the colours of the wings of moths and butterflies are due in some cases to pigments, in others to optical effects, and sometimes to a combination of the two; (2) that pigmental

colours are different shades of yellow, red, deep brown, or rarely white, green, and pure black; (3) that the white, yellow, and red pigments of the white or cabbage butterfly (*Pieridæ*), and possibly of other butterflies, are members of the uric-acid group, and (4) that the red, yellow, and white pigments, at least in the *Pieridæ*, are chemically nearly related, while the black and brown pigments differ markedly from them, and are of unknown chemical relations. Then, as shown by Mayer and others, in the development of colour in the chrysalis white or yellow tints appear, these growing darker as the insect develops, black always being the last to appear.

The present writer has noticed the same development of colour in the pupa of humble bees. At first the hairs of the half-formed pupa are colourless or whitish; shortly before the bee leaves its cell the hairs become darker, and finally black, the yellow bands being apparently the last to appear, unless they are of near the primitive colour, and have through inheritance failed to turn black, the original pale or yellowish hue surviving, but finally deepening in tone just before the bee leaves its cell and takes flight.

This interesting line of investigation has been recently taken up by others. Dr. M. Baer confirms Hagen's and Spuler's view that the particular tint may be due to the lines or dots or other markings of the individual scales, or to the combination of different scales. He finds that scales showing optical colours usually contain pigments in addition; but this pigment does not produce any marked effect on the colour, though it may be concerned in its production. Other apparently optical colours, such

as emerald green, peacock blue, violet, etc., are produced, he claims, by the superposition of scales containing pigment and scales giving off optical colours. The exact physical cause of the optical colours he did not ascertain. As regards pigmental colours, Baer classifies them into two types: diffused and granular. Pigments of the first type are diffused through the chitin or substance of the scale, are usually present in very small amount, and include the dark pigments, most yellow, orange, and red pigments, except in the *Pieridæ*, and the white pigment (uric acid) of the *Pieridæ*. Baer, as summarised by Newbigin in " Natural Science," also, contrary to the results of Hopkins, finds that some of the orange and yellow pigments of the *Pieridæ* are diffuse and not granular. Granular pigments occur exclusively in the *Pieridæ* and are yellow or red in colour. They colour the scales in which they occur very deeply. Such scales are few in number and almost without surface sculpturing. "The superposition of dark-coloured scales upon scales deeply tinted by yellow granular pigment may, as in *Anthochans cardamines*, produce a greenish tint."

Of a good deal of interest is the order of development of the colours, not only in the individual, but in the entire group of lepidoptera. As we have seen, the earliest shades to appear in the growing insect when in the chrysalis stage are first colourless, then yellowish white or yellow, then orange and orange red, the black tints being the last to appear. In a recent paper the Countess Maria von Linden confirms this view and finds that the black colour in butterflies is not due to a black pigment replacing the lighter ones, but to the fact that darkly col-

oured scales overlie light ones. She also discovered that optical colours, such as blue, appear later than the dark tints and are only exhibited by scales which contain dark pigment.

This leads us to the interesting question of the development of colour in the vast order of lepidopterous insects in general. Has there been a progressive development in colour? Of what hue were the earliest moths, and how did the later moths and the butterflies acquire their gorgeous styles of colouration? These problems are difficult to answer, but the progressive development of the colours of a single butterfly is most probably an epitome of the colour development in the order to which it belongs.

It is highly probable that the earliest, most primitive moths were, like the caddis flies, plain brownish; then some appeared with yellowish-brown or drab wings. We have caddis flies with spots and bars or stripes on their wings, but they are very few in number. The next step was the evolution in moths of bright markings. The wings of certain forms became striped or barred, and this style being of utility prevailed. Finally, moths with spotted wings—red, blue, and other colours—appeared here and there in conspicuous places; or the forewings became black and the hind wings red or yellow, these colours being interchangeable; and eye spots, like those on the hind wings of the Io moth and many butterflies, were the latest to appear. Somehow moths and butterflies with bright spots became abundant later in geological history, and the presence of such markings evidently had something to do with the preservation of the species. Hence a process of natural selection, or, better,

natural preservation, arose, and nearly all these gayly attired forms owe their comparative immunity from the destructive attacks of birds and lizards to the special arrangement of their markings.

In this connection the recent studies in the field by Herr M. C. Piepers, who has spent much time butterfly-hunting in eastern Asia, resulted in valuable suggestions. He shows that in certain of the eastern *Pieridæ* the amount of red in the wings varies greatly; that red and black vary inversely in amount; that in dimorphic species the male has usually more red and less black than the female, and that where the forewings contain much red, yellow occurs on the hind wings ; but when red is present in small amount, yellow is replaced by white. In brief, red and yellow on the one hand stand in antithesis to black and white on the other, and red tends to predominate in the males. He concludes that, in this group, red in itself, or in the forms of orange or yellow, is the most primitive colour in the family; that black and the dark tints are more specialised, and that, as they develop, the original red diminishes in amount and fades to orange, yellow, and ultimately white; but this view is questioned by Newbigin, and we think with good reason. Piepers, however, believes that the colours of butterflies tend to vary in a definite direction, that there is an evolution of colour.

These observations of Piepers and others indicate, as stated by Newbigin, that there is an intimate connection between the colours of the scales on the wings and other organs and their general structural peculiarities. In the Pierid butterflies the colours of individual scales do not change very markedly in development, but the early scales

with their primitive hues are covered up by scales bearing the hues of the perfect insect. In like manner in the adult, scales exhibiting the more primitive colours are of simple structure and " are replaced in phylogeny by scales of more complex structure and more specialised tint." And this shows, he adds, how far colour changes are from being superficial, and how intimately they are connected with the other characteristics of the animal.

Equal activity is being shown by chemico-biologists in the study of the colouring matter of flowers. It is now held that nearly all blue and red pigments originate from tannin; in other words, tannin constitutes the chromogen of the red and blue floral pigments. Keegan, in a recent article reviewing the subject, shows that the circumstances which created or influenced the particular tint of flowers is first chemical (the presence of quercetin in the form of rutin, etc., in the corolla), and, second, physiological, *i.e.*, " the possession by the corolla of energetic respiratory and transpiratory functions, with the result that the substances contained in its cells undergo an oxidation more or less vigorous and complete."

In this explanation of the cause of the differences of colour in flowers we hear nothing of natural selection as an active cause. Extreme Darwinians, however, like Wallace and others, insist that in the case of animals the colours are produced by "natural selection." But, in reality, natural selection is not an efficient, initiative cause; it only expresses the results of a series of causes, these being the effects of changes of temperature, light, etc.

As originally stated by Hagen in his able paper on the colours of insects, their hues are probably due to light and

air, while the other factors are changes in heat and cold, moisture and dryness, as well as in the structure of the scales in those insects possessing them.

The more we examine the subject the more clearly is it seen that we must depend on the action of these primary factors in the evolution of life. In the case of polar animals, their white colours are evidently due to cold. More black moths and butterflies occur in mountainous regions than elsewhere, and this melanism is due to cold and moisture. The faded-out appearance of desert animals is due to dryness, for animals which prey on others as well as those preyed upon are of the same general hue, as in the case of many insects, birds, reptiles, while the lion is tawny yellow, like the sands of waste places. The dry heat of the desert does not bring out gay colours, but in the semitropical regions adjoining them, where there is both heat and moisture, the bird and insect life is richly coloured. When green grasshoppers change to pink or yellow, as may happen in summer, but more usually in autumn, the cause appears to be a lower temperature.

There are still many unexplained problems in the matter of protective mimicry, but we are and have been for many years past convinced that the causes of the origin of colour and of colour variation are general and pervasive, both chemical and physiological, and due primarily to changes in the environment, while individual cases may be due to the biological environment or to the struggle for existence. Still the explanation of certain wonderful cases of mimicry is inadequate and needs further study.

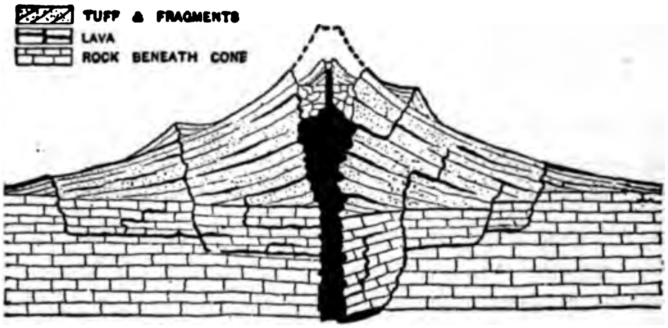
VI. VOLCANOES.

BY JAMES E. TALMAGE, Ph.D., F.R.S.E.

THE superstitions of the past found a ready explanation for all kinds of volcanic activity by referring such to supernatural causes, or by ascribing the same to the direct agency of mythological deities. One of the few volcanoes mentioned in ancient literature is Vulcano, a small representative of its class, situated on one of the Lipari isles in the Mediterranean. This deserves passing notice, as its name has been extended so as to cover all occurrences of the sort. Vulcano is represented in the myths of old as the workshop of the god Vulcan, and the fiery ejections issuing from the mountain were taken as proof of the deity's activity at forge and anvil. A similar fancy described Etna as the prison of another deity, who, vanquished by a superior power, had been thrust under the mountain; the disturbances incident to Etna's frequent eruptions were supposedly due to the vigorous but futile efforts of the imprisoned god to free himself from so uncomfortable a situation.

Even long after the science of geology had risen to prominence, vague and fanciful notions concerning volcanoes and associated phenomena were promulgated.

Thus the thought that "burning mountains" were dependent for their activity upon the combustion of the subterranean coal beds was seriously urged. As late as 1789 Werner spoke of the "highly probable conjecture that most if not all volcanoes arose from the combustion of underground seams of coal." Now, however, more rational views are held regarding the causes of volcanic action, yet the science of vulcanology is of but recent



IDEAL SECTION OF A VOLCANO.

origin. Scarcely more than a century has elapsed since the first well-directed efforts were instituted to collect and collate facts in this field of inquiry.

The most prominent idea suggested by the commonly accepted definition of a volcano is that of a mountain which manifests some sort of fiery energy. This, however, is not the essential feature, for, while it is true that the volcano is topographically indicated by some local elevation of the earth's crust, the characteristic occurrence is really that of a hole in the ground from which issue heated materials. The mountain is largely, and in most

cases almost wholly, due to the accumulation of these materials about the orifice in the form of a mound or cone, and such is therefore the result of the volcanic action. True, the elevation may be in part due to the lifting or arching of the crust by the operation of subterranean forces; indeed, cones of elevation are spoken of as distinguished from cones of eruption, but of the two the latter are the more important.

With respect to these cones of eruption, volcanic mountains are readily classified under two divisions:

1. Those with low, flat cones, consisting of true lava, or rock matter, which at the time of ejection was in a molten state. Of these there are many grades of slope, as determined by the liquidity of the lava and other conditions.

2. Those possessing steep cones, which are composed of rock matter in a more or less finely divided state, constituting what are known as volcanic "ashes" and "cinders."

The difference in the shape of these two types of cone is therefore seen to be dependent upon the nature of the ejected material—the liquid lava welling forth from the crater and covering a wide area before solidification is complete, while the volcanic "ashes" and "cinders" rest where they fall about the crater opening, and so build up a cone with steep sides. But there are other differences between these two types. Thus:

1. Volcanoes of the low cone, true lava kind, are comparatively quiet in eruption, the subterranean heat producing fusion of the rock, melting away the floor of the crater (which perhaps had hardened since the last pre-

ceding eruption) and permitting the lava to rise until it overflows. According to mode of eruption, volcanoes of this kind may be described as the quiet type; they are well illustrated by the volcanoes of the Hawaiian Islands.

2. Volcanoes with steep cinder cones usually erupt with violence; the conduit is cleared by explosive ejections; masses of rock torn from the underlying formations are hurled to great distances; finer rock matter in large quantities and immense volumes of steam and other vapours are belched forth, while violent earthquake disturbances may precede and accompany the eruptions. Such volcanoes may be described as of the explosive type; as examples the Javanese volcanoes may be mentioned.

Between these extreme types there are many intermediate varieties, emitting true lava as well as rock debris and vapours. Of these the European volcanoes in general are illustrative.

The prime cause of this distinction between the quiet and the explosive types appears to depend largely upon the kind of fusion to which the rock matter is subjected. If the temperature be sufficient under the existing conditions of pressure, etc., to melt the rock after the manner of dry fusion, true lava is produced and the eruption is of the characteristically quiet kind. But a semblance of fusion may result from a much lower temperature in the presence of moisture under pressure, and this is facilitated if alkaline matter be associated. The resulting liquefied rock presents the conditions of incipient fusion combined with those of solution under pressure; the product has been expressively called "rock broth," and the process is known as that of aqueo-igneous or hydrothermal fusion.

Now, as soon as the expansive forces are able to effect an outburst the pressure is relieved and the water flashes into vapour with terrific violence; the stony matter regains solidity, but in a finely divided state, and falls as "ashes" and "cinders."

The materials erupted are many and varied; among them may be named the lava, ashes, etc., already noted, and in addition large quantities of steam and such vapours and gases as hydrochloric, carbonic, and sulphurous acids; occasionally, also, boric acid and ammonia, probably some free hydrogen, and the vapours of such metals as mercury, antimony, and arsenic. Some of these chemical substances react among themselves and upon the materials of the rocks to produce a variety of other compounds; thus hydrochloric acid may combine with the iron present in the rocks with which the vapours come in contact to produce the bright yellow iron-chloride, and this when deposited about the vent is often mistaken for sulphur. Materials of economic value may be obtained from volcanic openings; *e.g.*, at historic Vulcano, where chemical works have been established for the preparation of sal ammoniac, boric acid, etc.

The fusibility of the lavas ejected from different volcanoes, and from the same volcano at different times, varies greatly, and corresponding differences are observed in the hardened rock. The Vesuvian lava stream of 1858 was of a highly viscid nature; the flow was slow, and the solidified rock is strikingly ropy. The same mountain in 1872 sent forth a flow of very liquid lava, which rapidly spread over the region and hardened with a rough, jagged surface.

The force required to produce volcanic eruptions is almost inconceivably great, and the energy of even a moderate outburst is appalling. It has been calculated that to raise the lava to the height of some active crater mouths requires a lifting power of hundreds of atmospheres; thus, for Vesuvius 325 atmospheric pressures are requisite; for Etna, 920; for Cotopaxi, 1,638. These calculations are based on the assumption that the condition of hydrostatic equilibrium would be at the sea level. It frequently happens that the mountain mass is unable to withstand the strain of this tremendous force operating within, and is riven from the central conduit outward; in such cases the rents are likely to become filled with the molten rock, which hardens, and by later erosion may be exposed as great dikes.

Then, further, the interior forces may find readier vent by making new openings on the mountain side or at its base. From these secondary craters ejections occur, and the erupted materials accumulate to form mounds or monticles. Etna rarely sends forth lava from the main crater, but emits copious flows from several openings near the base, each of which is associated with a monticle; this circumstance justifies the representation of Etna as a mother of mountains with her children around her.

The amount of material thrown out in the course of a single eruption is oftentimes enormous. Of recorded examples the following may be cited: In 1815 there was an eruption of Tomboro, a volcano on the island of Sumbawa; the ejected ashes and cinders were calculated at thirty-seven cubic miles, and the fall was so heavy that at a distance of forty miles houses were crushed by the load,

while 300 miles away the daytime darkness due to the volcanic dust was like that of the deepest night. The noise of this eruption was heard at a distance of nearly 1,000 miles. Vesuvius, in 1737, ejected nearly 12,000,000 cubic yards of rock matter, and in 1794 the mountain emitted over 22,000,000 cubic yards. In 1660 Etna disgorged a quantity of material equal to twenty times the volume of the mountain. Kilauea in 1840 sent forth lava which, according to the estimate of Professor Dana, was sufficient to cover a square mile to the depth of 800 feet.

Vesuvius, the only active volcano of considerable size on the mainland of Europe, is of historic note. For centuries prior to the Christian era it had been regarded as extinct; towns had gathered about its feet or had run up its slopes; vineyards and orchards of pomegranate and fig had taken possession of the rising approaches to its base, and the fertile volcanic soil was carpeted with flowers. A great earthquake occurred in A.D. 63, and gave warning of awakening energy, and in 79 a frightful eruption overwhelmed the cities of the Campanian plain, of which Pompeii and Herculaneum were the most important. Since the last date named Vesuvius had been in a state of intermittent and troubled activity. A disturbance was reported quite recently.

Kilauea, the chief of the Hawaiian volcanoes, presents the largest active crater on the earth, the opening being not less than three miles in circumference. The central pit, or "lake of fire," is an ever seething caldron of molten rock.

Of existing volcanoes over 500 are named and listed as of importance; but if the catalogue were to include open-

A View at 3:00 P.M.

A View at 3:15 P.M.

The Eruption of Vesuvius, April 26, 1872.

ings of smaller though of considerable extent and craters of moderate activity, many thousands would be comprised. The large volcanoes occur in groups or along lines near the ocean, the distribution suggesting some connection between the proximity of oceanic waters and the operation of volcanic forces. The occurrence in groups and lines may indicate a possible connection between the members of such a series and an interior reservoir or fissure. Common and violent as are volcanic outbursts, it appears to be certain that the vulcanism of the earth is waning, and that for the greatest exhibitions of volcanic power we must look to former geological ages. All crater eruptions may be regarded as incident to diminishing energy, for the great lava ejections of the past probably issued from immense fissures extending perhaps through many miles. Only from such fissures can we conceive of outpourings like those that have produced the lava flow of the northwestern part of our own country, covering 150,000 square miles, with a depth in places of 3,000 feet, or the Deccan lava field of India, which embraces an area of 200,000 square miles, with an observed depth of 6,000 feet.

Many theories have been devised to explain the source of the heat and the development of the force necessary to produce volcanic eruptions, but the discussion of such would exceed the limits set for the present paper.

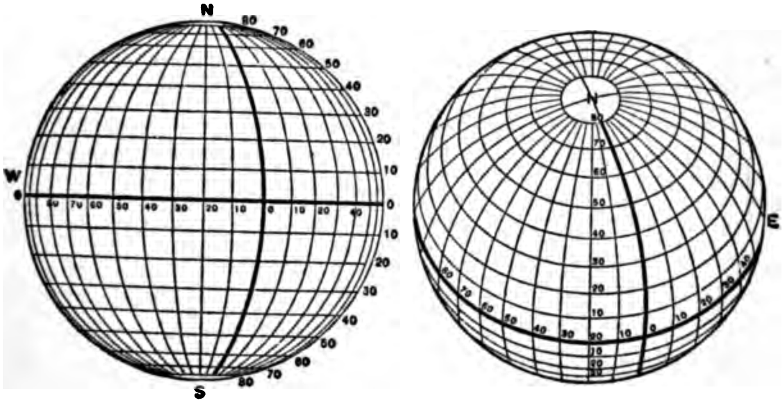
VII. TIME STANDARDS OF THE WORLD.

BY HAROLD JACOBY, Ph.D.

THE question is often asked, "What is the practical use of astronomy?" We know, of course, that it would be of the greatest value for men to study that science, even if it could not be turned to any immediate bread-and-butter use. For astronomy is essentially the science of big things, and it makes men bigger to fix their minds on problems that deal with vast distances and seemingly endless periods of time. No one can look upon the quietly shining stars without being impressed by the thought of how they burned then as now, before he himself was born, and so shall continue after he has passed away—aye, even after his latest descendants shall have vanished from the earth. Of all the sciences, astronomy is at once the most beautiful poetically, and yet the one offering the grandest and most difficult problems to the intellect. A study of these problems has ever been a labour of love to the greatest minds; their solution has justly been counted among man's loftiest achievements.

And yet of all the difficult and abstruse sciences, astronomy is perhaps the one that comes into the ordinary practical daily life of the people more definitely and frequently than any other. There are at least three things

that we owe to astronomy which may be regarded as quite indispensable from a purely practical point of view. In the first place let us consider the maps in a work on geography. How many people ever think to ask how these maps are made? It is true that the ordinary processes of the surveyor would enable us to draw a map showing the outlines of a part of the earth's surface. Even the location of the towns and rivers might be marked in this way.



LATITUDE AND LONGITUDE LINES.

But one of the most important things of all could not be added without the aid of astronomical observations. The latitude and longitude lines, which are essential to show the relation of the map to the rest of the earth, we owe to astronomy. The longitude lines particularly, as we shall see further on, play a most important part in the subject of time.

The second indispensable application of astronomy to ordinary business affairs relates to the subject of naviga-

tion. How do ships find their way across the ocean? There are no permanent marks on the sea, as there are on the land, by which the navigator can find his course. Nevertheless, the skilful seaman guides his vessel on the trackless ocean with a certainty as unerring as would be possible ashore. And it is all done by the help of astronomy. The navigator's observations of the sun are astronomical observations. The tables he uses in order to make his observations, which tell him just where he is and in what direction he must go, are astronomical tables. Indeed, it is not too much to say that without astronomy there could be no ocean navigation.

But the third application of astronomy is of still greater importance in our daily life. We refer to the furnishing of correct time standards for all sorts of purposes. It is to this use of astronomy that we would direct particular attention in the present article. Few persons ever think of the complicated machinery that must be put in motion in order to set a clock. A man forgets some evening to wind his watch at the accustomed hour. The next morning he finds it run down. It must be reset. Most people simply go to the nearest clock, or ask some friend for the time, so as to start the watch again correctly. More careful persons, perhaps, visit a jeweller's and take the time from his "regulator." But the regulator itself needs to be regulated. After all, it is nothing more than any other clock, except that greater care has been taken in the mechanical construction and arrangement of its various parts. Yet it is but a machine built by human hands, and like all human works it is necessarily imperfect. No matter how well it has been constructed, it will not run with

perfectly rigid accuracy. Every day there will be a variation from the true time by a small amount, and in the course of some days or weeks the accumulation of these successive small amounts will lead to a total of quite appreciable size.

Just as the ordinary citizen looks to the jeweller's regulator to correct his watch, so the jeweller applies to the astronomer for the correction of his regulator. Ever since the dawn of astronomy in the earliest ages of which we have any record, the principal duty of the astronomer has been the furnishing of accurate time to the people. We have not space to enter into a detailed account, however interesting it would be, of the gradual development by which the very perfect system at present in use has been reached. We must content ourselves with a description of the methods now employed in nearly all the civilised countries of the world. In the first place, every observatory is of course provided with what is known as an astronomical clock. This instrument, from the astronomer's point of view, is something very different from the ordinary popular idea. To the average person an astronomical clock is a complicated and elaborate affair, giving the date, day of the week, phases of the moon, and other miscellaneous information. But in reality the astronomer wants none of these things. His one and only requirement is that the clock shall keep as near uniform time as may be possible to a machine constructed by human hands. No expense is spared in making the standard clock for an observatory. Mechanical artists who have attained a world-wide celebrity for delicate skill in fashioning the parts of a clock are often employed by

astronomers from the most distant foreign countries. To increase precision of motion in the train of wheels it is necessary that the mechanism be as simple as possible. For this reason all complications of date, etc., are left out. They have even abandoned the convenient plan of having the hour and minute-hands mounted at the same centre. For this makes necessary a slightly more intricate form of wheel work. The astronomer's clock usually has the centres of the second-hand, minute-hand, and hour-hand in a straight line and equally distant from each other. Each hand had its own dial, all drawn of course upon the same clock face.

Even after such a clock has been made as accurately as possible it will, nevertheless, not give the very best performance unless it is taken care of properly. It is necessary to mount it very firmly indeed. It should not be fastened to an ordinary wall, but a strong pier of masonry or brick must be built for it on a very solid foundation. Moreover, this pier is best placed underground in a cellar, so that the temperature of the clock can be kept nearly uniform all the year round. For we find that clocks do not run quite the same in hot weather as they do in cold. Makers have indeed tried to guard against this effect of temperature by ingenious mechanical contrivances. But these are never quite perfect in their action, and it is best not to test them too severely by exposing the clock to sharp changes of heat and cold.

Another thing affecting the going of fine clocks, strange as it may seem, is the variation of barometric pressure. There is a slight but noticeable difference in their running when the barometer is high and when it is low. To pre-

THE EARTH DIVIDED INTO ZONES FOR RECKONING STANDARD TIME.

vent this some of our best clocks have been inclosed in air-tight cases, so that outside barometric changes may not be felt in the least by the clock itself.

But even after all this has been accomplished, and the astronomer is in possession of a clock that may be called a masterpiece of mechanical construction, he is not any better off than was the jeweller with his regulator. After all, even the astronomer's clock needs to be set, and its error must be determined from time to time. A final appeal must then be had to astronomical observations. The clock must be set by the stars and sun. For this purpose the astronomer uses an instrument called a "transit." This is simply a telescope of moderate size, possibly five or six feet long, and firmly attached to an axis at right angles to the tube of the telescope. This axis is held by supports in such a way that it points as nearly as may be exactly east and west. The telescope itself, being square with the axis, always points in a north and south direction. It is possible to rotate the telescope about its axis so as to reach all parts of the sky that are directly north or south of the observatory. In the field of view of the telescope certain very fine threads are mounted so as to form a little cross. As the telescope is rotated, this little cross traces out, as it were, a great circle on the sky. This great circle is called the astronomical meridian.

Now we are in possession of certain tables, computed from the combined observations of the astronomers of the last 150 years. These tables tell us the exact moment of time when any star is on the meridian. To discover, therefore, whether our clock is right on any given night, it is merely necessary to watch a star with the telescope

and note the exact instant by the clock when it reaches the little cross in the field of view. Knowing from the astronomical tables the time when the star ought to have been on the meridian, and having observed the clock-time when it actually was there, the difference is of course the error of the clock. The result can be checked by observation of other stars and the slight personal errors of observation can be rendered harmless by taking the mean from several stars. By an hour's work on a fine night it is possible in this way to fix the clock error quite easily within the one-twentieth part of a second.

We have not space to enter into the interesting details of the processes by which the astronomical transit is accurately set in the right position and how any slight residual errors in its setting can be eliminated from our results by certain processes of computation. It must suffice to say that practically all time determinations in the observatory depend substantially upon the process outlined above.

The observatory clock, having been once set right by observations of the sky, its error can be redetermined every few days quite easily. Thus, even the small irregularities of its nearly perfect mechanism can be prevented from accumulating until they should reach a harmful magnitude. But we obtain in this way only a correct standard of time within the observatory itself. How can this be made available for the general public? The process is quite simple with the help of the electric telegraph. We shall give a brief account of the methods now in use in New York City, and these may be taken as essentially representative of those employed elsewhere.

Every day at noon precisely an electric signal is sent out

by the United States Naval Observatory in Washington. This signal is regulated by the standard clock of the observatory, of course taking account of star observations made on the next preceding fine night. This signal is received in the central New York office of the telegraph company, where it is used to keep correct a very fine clock, which may be called the time standard of the telegraph company. This clock, in turn, has automatic electric connections, by means of which it is made to send out signals over what are called "time wires," that go all over the city. Jewellers and others who desire correct time can arrange to have a small electric sounder in their offices connected with the time wires. Thus the ticks of the telegraph company's standard clocks are repeated automatically in the jeweller's shop and used for controlling the exactness of his regulator. This, in brief, is the method by which the astronomer's careful determination of correct time is transformed and distributed to the people at large.

Having thus outlined the manner of obtaining and distributing correct time, we shall now consider the question of time differences between different places on the earth. This is a matter which many persons find most perplexing, and yet it is essentially quite simple in principle. Travellers are, of course, well acquainted with the fact that their watches often need to be reset when they arrive at their destination. Yet few ever stop to ask the cause. Let us consider for a moment our methods of measuring time. We go by the sun. If we leave out of account some small irregularities of the sun's motion that are of no consequence for our present purposes, we may lay

down this fundamental principle: When the sun reaches its highest position in the sky it is twelve o'clock, or noon. For the sun, as we know, rises each morning in the east, slowly goes up higher and higher in the sky, and at last begins to descend again toward the west. But it is clear that, as the sun travels from east to west, it must pass over the eastern one of any two cities sooner than the western one. When it reaches its greatest height over a western city it has, therefore, already passed its greatest height over an eastern one. In other words, when it is noon, or twelve o'clock, in the western city it is already afternoon in the eastern city. This is the simple and evident cause of time differences in different parts of the country. Of any two places the eastern one always has later time than the western. When we consider the matter in this way there is not the slightest difficulty in understanding how time differences arise. They will, of course, be greatest for places that are very far apart in an east and west direction. And this brings us again to the subject of longitude, which, as we have already said, plays an important part in all questions relating to time. For longitude is used to measure the distance in an east and west direction between different parts of the earth. If we consider the earth as a large ball we can imagine a series of great circles drawn on its surface and passing directly from the south pole to the north pole. Such a circle could be drawn through any point on the earth. If we imagine a pair of them drawn through two cities, such as New York and London, the longitude difference of these two cities is defined as the angle of the pole between the two great circles in question. The size of this angle can be

expressed in degrees. If we then wish to know the difference in time between New York and London in hours we need only divide their longitude difference in degrees by the number fifteen. In just this way we can get the time difference of any two places. We can measure the longitude difference on a map, and then divide by fifteen to get the time difference.

These time differences can sometimes become quite large. Indeed, for two places differing 180 degrees in longitude, the time difference will evidently be no less than twelve hours. Most of the civilised nations have agreed informally to adopt some one city as the fundamental point from which all longitudes are to be counted. Up to the present we have considered only longitude differences. When we speak of the longitude of any city we mean its longitude difference from the place chosen by common consent as the origin for measuring longitudes. The town almost universally used for this purpose is Greenwich, near London, in England. Here is situated the British Royal Observatory, one of the oldest and most important institutions of its kind in the world. The great longitude circle passing through the centre of the astronomical transit at the Greenwich observatory is the fundamental longitude circle of the earth. The longitude of any other town is then simply the angle at the pole between the longitude circle through that town and the fundamental Greenwich one here described.

Longitudes are counted both eastward and westward from Greenwich. Thus New York is in seventy-four degrees west longitude, while Berlin is in fourteen degrees east longitude. This has led to a rather curious state of

affairs in those parts of the earth whose longitude is nearly 180 degrees east or west. There are a number of islands in that part of the world, and if we imagine for a moment one whose longitude is just 180 degrees, we shall have the following remarkable result as to its time difference from Greenwich: We have seen that of any two places the eastern always has the later time. Now, since our imaginary island is exactly 180 degrees from Greenwich, we can consider it as being either 180 degrees east or 180 degrees west. But if we call it 180 degrees east, its time will be twelve hours later than Greenwich, and if we call it 180 degrees west, its time will be twelve hours earlier than Greenwich. Evidently there will be a difference of just twenty-four hours, or one whole day, between these two possible ways of reckoning its time. This circumstance has actually led to considerable confusion in some of the islands of the Pacific Ocean. The navigators who discovered the various islands naturally gave them the date which they brought from Europe. And as some of these navigators sailed eastward, around the Cape of Good Hope, and others westward, around Cape Horn, the dates they gave to the several islands differed by just one day.

The state of affairs at the present time has been adjusted by a sort of informal agreement. An arbitrary line has been drawn on the map of the world near the 180 degrees longitude circle, and it has been decided that the islands on the east side of this line shall count their longitudes west from Greenwich, and those west of the line shall count longitude east from Greenwich. Thus Samoa is nearly 180 degrees west of Greenwich, while the Fiji Islands are nearly 180 degrees east. Yet the islands are very near

each other, though the arbitrary line passes between them. As a result, when it is Sunday in Samoa it is Monday in the Fiji Islands. The arbitrary line described here is sometimes called the international date line. It does not pass very near the Philippine Islands, which are situated in about 120 degrees east longitude, and therefore use a time about eight hours ahead of Greenwich. New York, being about seventy-four degrees west of Greenwich, is about five hours behind in time. Consequently, as we may remark in passing, Philippine time is about thirteen hours ahead of New York time. Thus, five o'clock Sunday morning, May 1, in Manila, would correspond to four o'clock Saturday afternoon, April 30, in New York.

We shall conclude this article with a brief explanation of the so-called "standard" or railroad time, which came into general use in the United States some few years ago, and has since been pretty generally adopted throughout the world. It requires but a few moments' consideration to see that the accidental situation of the different large cities in any country will cause their local times to differ by odd numbers of hours, minutes, and seconds. Thus a great deal of inconvenience has been caused in the past. For instance, a train might leave New York at a certain hour by New York time. It would then arrive in Buffalo some hours later by New York time. But it would leave Buffalo by Buffalo time, which is quite different. Thus there would be a sort of jump in the time-table at Buffalo, and it would be a jump of an odd number of minutes. It would be different in different cities, and very hard to remember. Indeed, as each railway usually ran its trains by the time used in the principal city along its line, it

might happen that three or four different railroad times would be used in a single city where several roads met. This has all been avoided by introducing the standard time system. According to this, the whole country is divided into a series of time zones, fifteen degrees wide, and so arranged that the middle of each zone falls at a point whose longitude from Greenwich is 60, 75, 90, 105, or 120 degrees. The times at these middle points are therefore behind Greenwich time by an even number of hours. Thus the seventy-five degree point is just five hours behind Greenwich time. All cities, then, simply use the time of the nearest one of these special points. The effect of this is not to do away with time differences altogether. That would manifestly be impossible from the nature of things. But for the complicated odd differences in hours and minutes we have substituted the infinitely simpler series of differences in even hours. The traveller from Chicago to New York can reset his watch by putting it just one hour ahead. The minute-hand is kept unchanged, and no New York timepiece need be consulted to set the watch right on arriving. There can be no doubt that the standard time system must be considered as one of the most important contributions of astronomical science to the convenience of man.

VIII. THE FORMATION OF COAL.

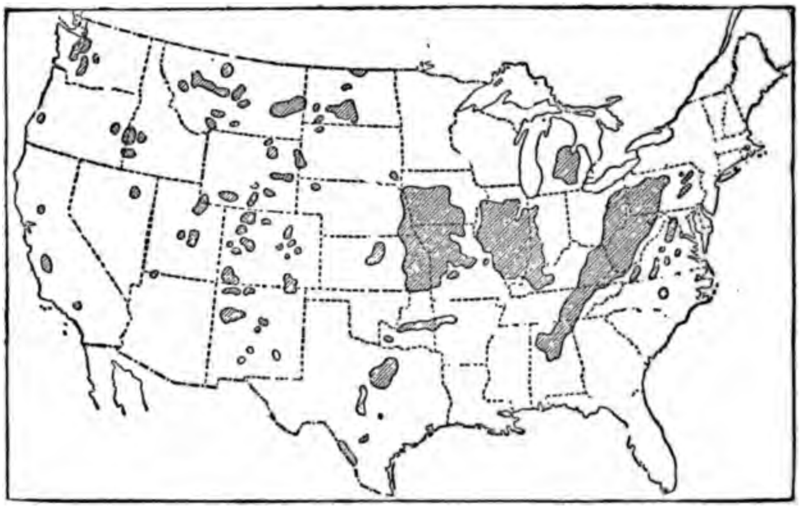
By Samuel Calvin, A.M., Ph.D.

IMPORTANCE OF COAL.

Beyond question coal is one of the most important of all the geological products. It is the agent employed, directly or indirectly, to furnish needed artificial warmth and light in all the great civilised centres of human population. Commerce, manufactures, means for travel by sea and land—all the great industries and processes which are concerned in the production and distribution of objects that minister to our material comfort or gratify our intellectual or æsthetic wants—are at some point and in some degree dependent on continual supplies of coal. We have but recently learned how important is coal to the nation which aspires to naval supremacy. It is equally important to the nation which would win commercial, manufacturing, or intellectual supremacy. Our present civilisation is largely based on coal. The annual consumption of this fuel reaches the enormous aggregate, in round numbers, of 600,000,000 tons. The genesis of an object so extensively used and so universally necessary is well worthy of consideration.

GEOLOGICAL AGE OF COAL.

Coal has been formed during more than one of the geological periods, but the coal beds of greatest commercial importance are of the carboniferous age. There are, indeed, no coal deposits worthy of consideration in formations older than the upper carboniferous. From this it



COAL FIELDS OF THE UNITED STATES.

follows that all land areas within which the surface rocks belong to these older formations are areas within which coal is impossible, and the quest for it utterly hopeless. There is a popular and general impression that coal is as likely to be found in one part of the continent as in another, and that it is, in fact, certain to be discovered at any given point provided only the borings or other methods of

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search are carried deep enough. It ought to be obvious that if the surface rocks of any given area are, for example, of Devonian age, the foundations of the region were finished before coal plants grew or coal beds formed, and borings begun in any such area will pass successively through older and older beds, in which the expectation of finding coal has less and less hope of being realised. As well might one expect to find a technical description of photography or the art of printing among manuscripts of the first century as to expect to find coal among rocks that were finished before the world had reached the stage which made coal-making possible. That stage was first reached in the upper carboniferous, and since then coal-making, or some analogous process, has been going forward wherever the conditions were favourable.

KINDS OF COAL.

In this paper the discussions will be limited chiefly to coal formed during the carboniferous period. It has already been said that the most important coal beds are of carboniferous age. It would be safe to go further and say that carboniferous coal easily exceeds in value the coal of all the later geological ages put together. The coal of the carboniferous varies greatly as to kind and quality. The most common and the most widely known of the several kinds is that called bituminous coal. It is the "soft coal" of commerce; the coal which, by distillation—heating in air-tight retorts or ovens—may be made to yield gas, oil, tar, and a number of other distillates; while the residual product is the hard, porous substance

Surface Coal Strippings at the Shenandoah City Colliery, Pa.

From a photograph by Rau.

known as coke. Next, in the extent to which the public comes in daily contact with it, is anthracite coal. This is the "hard coal" of the coal markets. It is a hard, compact, structureless coal, breaks with smooth, glossy surfaces, has high specific gravity, and burns with little or no flame. It yields but small amounts of the distillates derivable from typical bituminous coal. Between the soft bituminous and the hard anthracite, however, there are numberless intermediate grades, some of which are known as semi-bituminous and semi-anthracite. Cannel coal is a fine-grained, compact, dense variety of bituminous coal, the better grades of which are allied to jet and are capable of taking a high polish. Gas coal, steam coal, furnace coal, coking coal, and similar terms are trade names for different varieties and intergradations of the kinds above described.

COAL IS OF VEGETABLE ORIGIN.

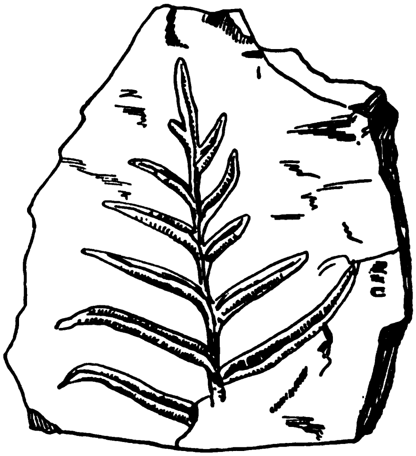
It need scarcely be said that coal was made from plants. The evidence of its vegetable origin lies on the surface of many a piece of bituminous coal. Especially is it true that on the soft coals of such regions as Illinois and Iowa—regions which have suffered little disturbance in the matter of crushing and folding of the strata, and in which the material forming the coal has undergone least change since it was deposited—the casual observer, even, may note the outward form and fibrous structure of flattened plant stems reduced to a condition somewhat resembling charcoal. While much of the coal is compact, vitreous in appearance, structureless, there are planes and thin

seams along which the original plant tissues are well preserved. Here there is the clearest evidence of stems crossed and recrossed and packed together in all the disorderly confusion that obtains among the stems and leaves of meadow plants in bales of pressed hay. The carbon-

COAL UNDER THE MICROSCOPE.

ised bark, or cortex, of carboniferous plants, still bearing the characteristic scars or markings, may often be recognised as constituent parts of lumps of soft coal. Under the microscope the evidence is even more satisfactory, for the soft, fibrous, charcoal-like portions require but very simple treatment to show the cellular structure—particularly the fibro-vascular bundles—of the higher spore-bearing plants. Scalariform ducts and other peculiarly marked vessels lie beneath the lens, mingled with opaque, coal-black fibres, but retaining perfectly—notwithstanding the measureless reaches of time since that far-off carboniferous, and in spite of the changes that chemical and

physical forces have constantly been bringing about in the materials forming the earth's crust—the minute, microscopic characteristics which distinguished them when they were essential parts of the living plants that gave charm and beauty to the late paleozoic landscapes.

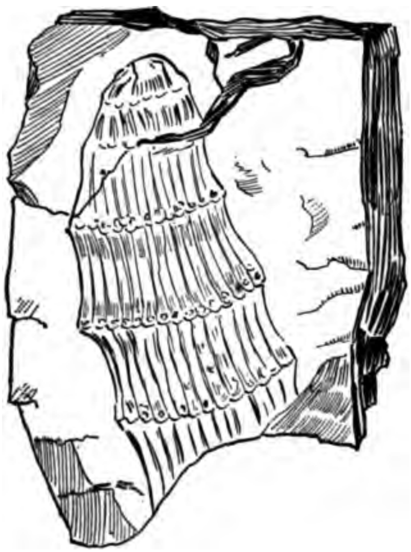


COAL SHALE.

With more refined methods of preparation the cellular structure of much of the coal is better revealed, and the fact that some beds, or portions of beds, are largely made up of the dust-like spores of pteridophytes—fern plants—becomes susceptible of demonstration.

Coal is usually overlaid by dark-coloured shale or "slate." Sometimes the coal becomes more and more stony toward the top of the seam and passes gradually into the overlying shale. The roof shale may generally be split into thin leaves, and upon the surface of these

leaves the impressions of fern fronds often occur in wonderful profusion, the tracery the most delicate imaginable, every pinnule in place, and the minutest detail of venation and surface markings perfectly preserved. Plants certainly contributed the carbonaceous material of the



COAL SHALE.

dark-coloured roof shales and of the transition beds between shale and coal. Without pursuing the evidence further, it may be said that all lines of observation and inquiry converge toward the one simple conclusion that coal, in all its qualities and varieties, is a gift from the vegetable kingdom.

THE COAL PLANTS OF THE CARBONIFEROUS PERIOD.

There has been some diversity of opinion concerning the kinds of plants which contributed to the formation of coal. Coal seams usually occur interstratified with shale, sandstone, or limestone. In most cases the overlying and underlying stony beds bear unmistakable evidence of having been deposited as sediment on the bottom of an ancient ocean. The coal itself seems often to have been accumulated under sea-water. These and other patent facts have led some observers to conclude that coal is a product of sea-weed, made up by settling to the bottom, and entombed under subsequently deposited sediments, of tangled masses of kelp or fucus, such as float on the surface of the modern Sargasso Sea. While this view may afford a correct explanation of the genesis of some coal seams, the evidence is clear that the principal part of the coal in the interior of the North American continent was derived from terrestrial, or semi-terrestrial, vegetation. The coal itself, however investigated, the roof shales, the associated sandstones—all the records of the time—tell of a marvellous development of ferns and related plants—the pteridophytes of modern botany—growing in moist and marshy places, sometimes with roots submerged, but with the green foliage and fruiting parts of the plants lifted in the air and exposed to the sunshine. Fronds, leaves, and spores continually fell from the over-rank vegetation, while trunks and branches of tree-like forms, by accident of storms or natural death, were from time to time added to the blackened, half-decayed, water-soaked

mass of peat-like material with which the marsh was gradually being filled.

The most abundant vegetation of the carboniferous period was ferns. The species were numerous. Many were of royal proportions. Their fronds lie, spread out in all the perfection attainable in the best herbaria, between the laminæ of the roof shales. Stems of curious tree-ferns are preserved in beds of carboniferous sandstone. The characteristic fibro-vascular bundles of stems and fronds are revealed in perfection by the microscope in the very substance of the coal.

Along with the ferns grew various genera of plants related to the lycopodium, the common ground-pine or club-moss. Two are worthy of special notice. Both grew to the dignity of trees, with trunks ranging up to three feet in diameter and a height varying from thirty to seventy, or occasionally a hundred, feet. Both were sparsely branched, and the branches were stiff and clumsy. The foliage was similar in both cases, and consisted of short, pointed, spike-like leaves attached by thickened bases to stem or branch. The reproductive bodies were dust-like spores produced away out at the extremities of the branches, in the axils of scales or modified leaves. In one case the leaves were thick-set upon the surface, their bases touching all around, the foliage-bearing part of the plant fairly bristling with green spikes. The leaves were, however, progressively shed from all but the upper growing parts, and the bare stems were sculptured with diamond-shaped leaf scars in a pattern resembling the arrangement of scales on certain ganoid fishes. This was the lepidodendron, or scale-tree. The other great lycopod had the

A Forest of the Coal Period.

stem longitudinally fluted, with leaf scars arranged in rows along the ribs or in the furrows between them. From a fancied resemblance of these leaf scars to impressions of the old-fashioned seal in softened wax this type has been called sigillaria, the seal-tree.* Besides lepidodendron and sigillaria there were reed-like pteridophytes related to the modern horse-tails or scouring rushes. Some of these, with jointed stems and fine flutings between the nodes, are known as calamites. Less common in the swampy jungles, but more abundant, apparently, on the drier uplands were numerous cone-bearing trees, some with broad leaves related to the curious gingko, the salisburia, of our modern flora, and others more nearly allied to the present yews and pines. Ferns, lepidodendrons, sigillarias, calamites, and old-fashioned conifers all contributed in greater or less degree to the formation of coal.

THE COAL OF THE CARBONIFEROUS AGE ACCUMULATED IN ESTUARIES OR IN SEA-BORDER MARSHES.

The unparalleled luxuriance of the carboniferous forests extended to the more open sylva of the uplands, as well as

* It is possible that plants of different rank, and hence referable to different orders of the vegetable kingdom, had stems longitudinally fluted and marked with the seal-like scars which have been regarded as the distinguishing characteristics of sigillaria. At all events different observers have come to widely different conclusions respecting the systematic position of sigillaria, some referring it without question to the lycopods and others regarding it as related to cycads—a group of gymnospermous plants belonging to the same sub-order as the pines and spruces. Fragments of stems of sigillaria from the coal measures of Guthrie County, Iowa, unusually well preserved and showing the microscopic details of structure as perfectly as if sections had been cut from the fresh stem, have for some time been in possession of the writer. Microscopic sections from these reveal the scalariform tissue of pteridophytes and not the gymnospermous tissue of cycads. The sigillaria from the coal measures of Iowa is certainly related to ferns and lepidodendrons more intimately than to cycads.

MAMMOTH COAL VEIN A MILE UNDERGROUND.

(Kohinoor Colliery, Shenandoah City, Pa.)

to the dense jungles of the salt marshes and brackish estuaries, but it was only where conditions favoured the partial or complete submergence of accumulations of vegetable matter that coal was formed. Plant remains falling on dry land and exposed to the atmosphere undergo complete decay and soon return to earth and air. The inconceivable volume of vegetable debris which must have been furnished by the successive generations of forests occupying eastern America before the Columbian discovery, except the very small amount locally preserved in swamps, has long since entirely disappeared as a result of atmospheric decay.

The picture of carboniferous time suggested by a study of the coal-measures shows that the shore lines, in place of being where they are now, coincided in a general way with the coal-bearing belts of the present continents. The lands were relatively low, and extensive marshes bordered the continental areas. Within the marshes and along their moist margins, plants, mostly pteridophytes, grew with astonishing vigour, and annually cast leaves and fronds and spores and fallen trunks, ton after ton to the acre, into dark-brown pond water, which had become a strong infusion of decaying vegetable tissues. The sodden plant remains were blackened and only partially decayed, because the air was largely excluded; and the peaty water itself exercised preservative effects. The amount of carbonised plant tissues gathered in any given place depended on the area and depth of the marsh, and on the length of time the land maintained the same relations to sea level. The crust, however, was unstable. Elevation and subsidence caused the shore lines to retreat or ad-

vance with reference to the land, and the coal marshes shifted position from time to time within certain limits. When the sea encroached, marshes, with all their accumulated stores of carbon were submerged, and the half-formed coal was buried under beds of shale and sandstone which were spread out as sediments on the sea bottom. Elevation of the crust caused the sea to retreat, and many times it happened that the conditions of marsh and coal accumulation were reëstablished directly over the location of an old buried swamp. Thus it is that in the coal-measures it is not uncommon to find a number of coal seams one over the other and separated by earthy deposits in the form of shale or sandstone. Coal was formed in shallow estuaries, at the mouths of rivers, as well as in isolated marshes, and so part of the material forming some coal seams may have reached its resting-place as driftwood swept down from the uplands by flooded drainage streams. Much the greater part of our American coal, however, seems to be the product of accumulations of vegetable detritus in the place where the plants grew.

THE TRANSFORMATION OF PLANT REMAINS INTO COAL.

Coal, as we now know it, is the resultant of a series of changes which have been taking place in the beds of vegetable remains ever since they were buried under marine sediments during the remote carboniferous age. The material has been compacted and consolidated by pressure. It has everywhere undergone chemical changes similar to those that rapidly take place when coal is sub-

jected to destructive distillation in gas retorts or coke ovens. Gases have been evolved, and the residue has been forming new chemical combinations. Changes have taken place more rapidly in some localities than in others, and so all gradations are found from the soft bituminous coal of the Mississippi valley, where the changes are comparatively slight, to the hard anthracite of Pennsylvania, which represents almost the final product of distillation of coal in place. Every step and stage in the process of transforming wood to anthracite may be brought about artificially, in properly constructed retorts, in a comparatively short time. In nature the process has been slow. In Iowa and Illinois it is not far advanced even now. In the mountains of Pennsylvania, where the crushing and folding of the crust were attended by the conversion of mechanical energy into heat on a large scale, and elsewhere where volcanic energy has been exerted in connection with coal-bearing strata, the distillative processes have been hastened, and the outcome is that to which all the soft coals of the world are slowly tending, namely, anthracite. In Rhode Island there is a small coal area in which the process of change has been carried further than in the mountains of Pennsylvania. There the coal has become in part graphitic anthracite, which it is difficult to make burn at all, and in part it is graphite, which it is impossible to use as fuel. Graphite is the final residual product in the destructive distillation of vegetable tissues.

At Kimberley, in South Africa, the famous diamond mines are operated in a carbonaceous shale, which has suffered profound alteration by reason of the intrusion of volcanic rocks in a melted condition. The carbonaceous

material of the shale was subjected under pressure to the high temperature of melted rocks, and one of the products —derivative, probably, not residual—is the most royal of all gems, pure, crystallised carbon.

Growing forests, peat, brown coal, bituminous coal, anthracite, and graphite, with all the numerous intergrading variations, are but terms of a single series, and closely related to this plebeian and useful series is the royal diamond.

IX. THE NEW PLANET OF 1898.

BY HAROLD JACOBY, Ph.D.

THE discovery of a new and important planet usually receives more immediate popular attention and applause than any other astronomical event. Philosophers are fond of referring to our solar system as a mere atom among the countless universes that seem to float within the profound depths of space. And then they are wont to point out that this solar system, small and insignificant as a whole in comparison with many of the stellar worlds, is nevertheless made up of a large number of constituent planets. These in turn are often accompanied with still smaller satellites or moons. Thus does nature provide worlds within worlds, and it is but natural that public attention should be at once attracted by any new member of our sun's own special family of planets. The ancients were acquainted with only five of the bodies now counted as planets; viz., Mercury, Venus, Mars, Jupiter, and Saturn. The dates of their discovery are lost in antiquity. To these Uranus was added in 1781 by a brilliant effort of the elder Herschel. We are told that intense popular excitement followed the announcement of Herschel's first observation. He was knighted and otherwise honoured by the English king, and was enabled to lay a secure foun-

dation for the future distinguished astronomical reputation of his family.

Herschel's discovery quickened still further the restless activity of astronomers. Persistent efforts were made to sift the heavens more and more closely, with the hope of adding still further to our planetary knowledge. An association of twenty-four enthusiastic German astronomers was formed for the express purpose of hunting planets. But it fell to the lot of a Sicilian, Piazzi of Palermo, to find the first of that series of small bodies now known as the asteroids or minor planets. He made the discovery at the very beginning of the century, January 1, 1801. But news travelled slowly in those days, and it was not until nearly April that the German observers heard from Piazzi. In the meantime he had himself been prevented by illness from continuing his observations. By a further unfortunate set of circumstances the planet had by that time moved so near the sun, on account of the motions of the planet and earth, that it could no longer be observed. The bright light of the sun made observation of the planet impossible. It was therefore feared that owing to lack of knowledge of the planet's orbit astronomers would be unable to trace it. So there seemed indeed to be danger of an almost irreparable loss to science. But in scientific, as in other human emergencies, some one always appears at the proper moment. A very young mathematician at Göttingen, named Gauss, attacked the problem, and was able to devise a method of predicting the future course of the planet on the sky, using only the few observations made by Piazzi himself. Up to that time no one had attempted to compute a planetary orbit, unless he had

at his disposal a series of observations extending throughout the whole period of the planet's revolution around the sun. But the Piazzi planet offered a new problem in astronomy. It had become imperatively necessary to obtain an orbit from a few observations made at nearly the same date. Gauss' work was signally triumphant, for the planet was duly found in the position predicted by him, as soon as a change in the relative places of the planet and sun permitted a study to be made.

But after all Piazzi's planet belongs to a class of quite small bodies, and is by no means as interesting as Herschel's discovery of Uranus. But even this must be relegated to second rank among planetary discoveries. On September 23, 1846, the telescope of the Berlin observatory was directed to a certain point on the sky for a very special reason. Galle, the astronomer of Berlin, had received a letter from Leverrier of Paris, telling him that if he would look in a certain direction he would detect a new and large planet. Leverrier's information was based upon a mathematical calculation. Seated in his study, with no instruments but pen and paper, he had slowly figured out the life history of a world as yet unseen. Tiny discrepancies existed in the observed motions of Herschel's planet Uranus. No man had explained their cause. To Leverrier's acute understanding they slowly shaped themselves into the possible effects of attraction emanating from some unknown planet exterior to Uranus. Was it conceivable that these slight tremulous imperfections in the motion of a planet could be explained in this way? Leverrier was able to say, confidently, "Yes." But we may rest assured that Galle had but small hopes that upon his eye, of all

myriad eyes of men, would fall the first ray of the new planet's light. Careful and methodical, he would neglect no chance of advancing his beloved science. He would look. Only one who has himself often seen the morning's sunrise put an end to a night's delightful contemplation of the stars can hope to appreciate what Galle's feelings must have been when he saw the planet. To his trained eye it was certainly recognisable at once. And then the good news was sent on to Paris. We can imagine Leverrier, the cool calculator, saying to himself: "Of course he found it. It was a mathematical certainty." Nevertheless his satisfaction must have been of the keenest. No triumphs give a pleasure higher than those of the intellect. Let no one imagine that men who make researches in the domain of pure science are underpaid. They find their reward in pleasure that is beyond any price.

The Leverrier planet was found to be the last of the so-called major planets, so far as we can say in the present state of science. It received the name Neptune. Observers have found no other members of the solar system comparable in size with such bodies as Uranus and Neptune. More than one eager mathematician has tried to repeat Leverrier's achievement, but the supposed planet was not found. It has been said that figures never lie; yet such is the case only when the computations are correctly made. People are prone to give to the work of careless or incompetent mathematicians the same degree of credence that is really due only to masters of the craft. It requires the test of time to affix to any man's work the stamp of true genius.

While, then, we have found no more large planets, quite

a group of companions to Piazzi's little one have been discovered. They are all small, none probably exceeding about 400 miles in diameter. All travel around the sun in orbits that lie wholly within that of Jupiter and are exterior to that of Mars. The introduction of astronomical photography has given a tremendous impetus to the discovery of these minor planets, as they are called. It is quite interesting to examine the photographic process by which such discoveries are made possible and even easy. The matter will not be difficult to understand if we remember that all the planets are continually changing their places among the other stars. For the planets travel around the sun at a comparatively small distance. The great majority of the stars, on the contrary, are separated from the sun by an almost immeasurable space. As a result they seem not to move at all among themselves, and so we call them fixed stars. They may, indeed, be in motion, but their great distance prevents our detecting it.

Now, stellar photographs are made in much the same way as ordinary portraits. Only, instead of using a simple camera, the astronomer exposes his photographic plate at the eye-end of a telescope. The sensitive surface of the plate is substituted for the human eye. We then find on the picture a little dot corresponding to every star within the photographed region of the sky. But, as every one knows, the turning of the earth on its axis makes the whole heavens, including sun, moon, and stars, rise and set every day. So the stars, when we photograph them, are sure to be either climbing up in the eastern sky or else slowly creeping down in the western. And that makes astronomical photography very different from ordinary

portrait work. For the stars correspond to the sitter, but they don't sit still. For this reason it is necessary to connect the telescope with a mechanical contrivance which makes it turn round like the hour-hand of an ordinary clock. The arrangement is so adjusted that the telescope, once aimed at the proper object in the sky, will move so as to remain pointed exactly the same during the whole time of the photographic exposure. Thus, while the light of any star is acting on the plate, such action will be continuous at a single point. Consequently the finished picture will show the star as a little dot. If it were not for this arrangement the star would trail out into a line instead of a dot. Now we have seen that the planets are all slowly moving among the fixed stars. So if we make a star photograph in a part of the sky where a planet happens to be, the planet will make a short line on the plate. If the planet remained quite unmoved relatively to the stars it would give a dot like the star dots. The presence of a line, therefore, at once indicates a planet.

This method of planet-hunting has proved most useful. More than 400 small planets similar to Piazzi's have been found, though never another one like Uranus and Neptune. But, as we have said, these little planets lie between Mars and Jupiter. They evidently belong to a group or family, and many astronomers have been led to believe that they are but fragments of a former large planet.

In August, 1898, however, one was found, by Witt of Berlin, which will probably occupy a very prominent place in the annals of astronomy. For this planet goes well within the orbit of Mars, and this will bring it at times very

close to the earth. In fact, when the motions of the new planet and the earth combine to bring them to their positions of greatest proximity the new planet will approach us closer than any other celestial body except our own moon. Witt named his new planet Eros. The size of Eros is probably sufficient to bring it within the possibilities of naked-eye observation at the time of closest approach to the earth. The last favourable opportunity occurred in November, 1900, when the planet was observable easily from all parts of the United States.

To astronomers the great importance of this new planet is due to the following circumstance: For certain reasons we have not space to state in detail, the distance from the earth to any planet can be determined with a degree of precision which is greatest for planets that are near us. Thus in time we shall learn the distance of Eros more accurately than we know any other celestial distance. From this, by a process of calculation, the solar distance from the earth is determinable. But the distance from earth to sun is the fundamental astronomical unit of measure. Thus Witt's new discovery, through its effect on the unit of measure, may be expected to influence every part of the science of astronomy. Here once more we have a striking instance of the reward sure to overtake the diligent worker in science. A whole generation of men will doubtless come and go before we shall have exhausted the scientific advantages to be drawn from Witt's remarkable discovery of 1898.

X. *THE WOBBLING OF THE EARTH'S POLE.*

BY HAROLD JACOBY, Ph.D.

STUDENTS of geology have been puzzled for many years by traces remaining from the period when a large part of the earth was covered with a heavy cap of ice. These shreds of evidence all seem to point to the conclusion that the centre of the ice-covered region was quite far away from the present position of the north pole of the earth. If we are to regard the pole as very near the point of greatest cold, it becomes a matter of much interest to examine whether the pole has always occupied its present position, or whether it has been subjected to slow changes of place upon the earth's surface. Therefore the geologists have appealed to astronomers to discover whether they are in possession of any observational evidence tending to show that the pole is in motion.

Now, we may say at once that astronomical research has not as yet revealed the evidence thus expected. Astronomy has been unable to come to the rescue of geological theory. From about the year 1750, which saw the beginning of precise observation in the modern sense, down to very recent times, astronomers were compelled to deny the possibility of any appreciable motion of the pole. Observational processes, it is true, furnished

slightly divergent pole positions from time to time. Yet these discrepancies were always so minute as to be indistinguishable from those slight personal errors that are ever inseparable from results obtained by the fallible human eye. But within the last few years improved methods of observation, coupled with extreme diligence in their application by astronomers generally, have brought to light a certain small motion of the pole which had never before been demonstrated in a reliable way. This motion, it is true, is not of the character demanded by geological theory. For the geologists had been led to expect a motion which would be continuous in the same direction, no matter how slow might be its annual amount. For the vast extent of geologic time would give even the slowest of motions an opportunity to produce large effects, provided its results could be continuously cumulative. Given time enough, and the pole might move anywhere on the earth, no matter how slow might be its tortoise speed.

But the small motion we have discovered is neither cumulative nor continuous in one direction. It is what we call a periodic motion, the pole swinging now to one side, and now to the other, of its mean or average position. Thus this new discovery cannot be said to unravel the mysterious puzzle of the geologists. Yet it is not without the keenest interest, even from their point of view. For the proof of any form of motion in a pole previously supposed to be absolutely at rest may mean everything. No man can say what results will be revealed by the further observations now being continued with great diligence.

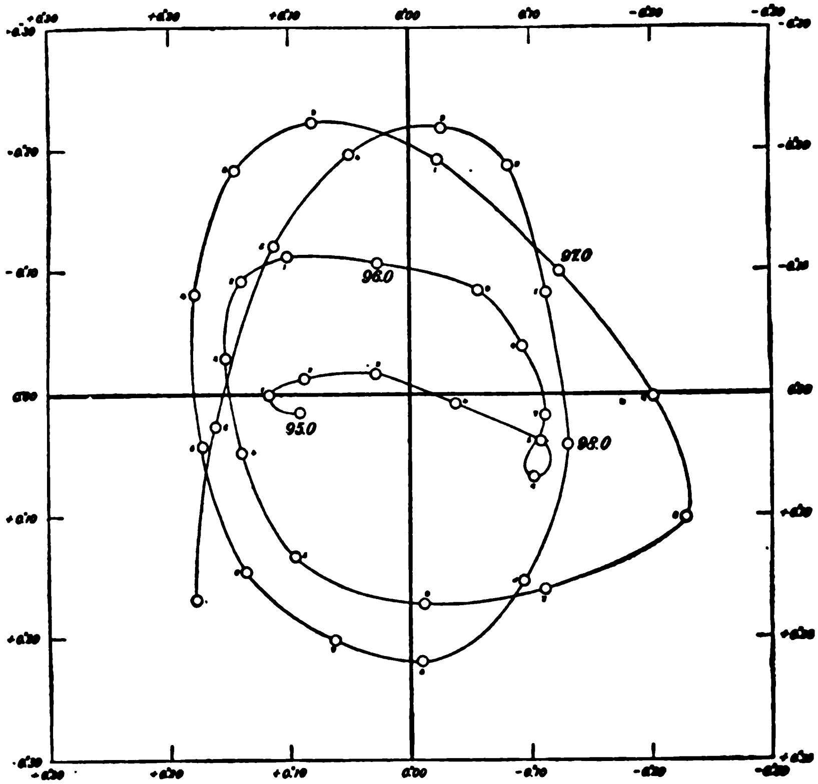
In the present article we propose to consider only those

motions or wobblings of the pole that have been ascertained to be definite facts. In the first place, it is important to explain that any such motions as we have under consideration will show themselves to ordinary observational processes principally in the form of changes of terrestrial latitude. Let us imagine a pair of straight lines passing through the centre of the earth and terminating, one at the observer's station on the earth's surface, and the other at that point of the equator which is nearest to the observer. Then, according to the ordinary definition of latitude, the angle beween these two imaginary lines is called the latitude of the point of observation. Now we know, of course, that the equator is everywhere just ninety degrees from the pole. Consequently, if the pole is subject to any motion at all, the equator must also partake of the motion. Thus the angle between our two imaginary lines will be affected directly by polar wobbling, and the latitude obtained by astronomical observation will be subject to quite similar changes. To clear up the whole question, so far as this can be done by the gathering of observational evidence, it is only necessary to keep up a continuous series of latitude determinations at several observatories. These determinations should show small variations similar in magnitude to the wobblings of the pole.

Let us now consider for a moment what is meant by the axis of the earth. It has long been known that this planet has in general the shape of a ball or sphere. That this is so can be seen at once from the way ships at sea gradually disappear at the horizon. As they go farther and farther from us, we first lose sight of the hull, and then slowly

and gradually the spars and sails seem to sink down into the ocean. This proves that the earth's surface is curved. That it is more or less like a sphere is evident from the fact that it always casts a round shadow in eclipses. Sometimes the earth passes between the sun and the eclipsed moon. Then we see the earth's black shadow projected on the moon, which would otherwise be quite bright. This shadow has been observed in a very large number of such eclipses, and it has always been found to have a circular edge.

While, therefore, the earth is pretty nearly a round ball, it must not be supposed that it is exactly spherical in form. We may disregard the small irregularities of its surface, for even the greatest mountains are insignificant in height when compared with the immense diameter of the earth itself. But even leaving these out of account, the earth is not perfectly spherical. It is best described as a flattened sphere. It is as though one were to press a round rubber ball between two smooth boards. It would be flattened at the top and bottom and bulged out in the middle. This is precisely the shape of the earth. It is flattened at the poles and bulges out near the equator. The shortest straight line that can be drawn through the earth's centre and terminated by the flattened parts of its surface may be called the earth's axis of figure. The two points where this axis meets the surface are called the poles of figure. But the earth has still another axis, called the axis of rotation. This is the one about which the earth turns once in a day, giving rise to the well-known phenomena called the rising and setting of the sun, moon, and stars. For these motions of the heavenly bodies are



CURVE SHOWING THE OBSERVED MOTION OF THE EARTH'S POLE FROM 1895 TO 1899.

(The motions are shown in hundredths of a second of arc, corresponding to a linear distance of one foot.)

really only apparent ones, caused by an actual motion of the observer on the earth. The observer turns with the earth on its axis, and is thus carried past the sun and stars. These, then, seem to rise, pass over the observer, and set again, much as houses and fields seem in motion to a person seated in a fast railroad train.

This daily turning of the earth, then, takes place about the axis of rotation. Now, it so happens that all kinds of astronomical observations for the determination of latitude lead to values based on the rotation axis of the earth, and not on its axis of figure. We have seen how the earth's equator, from which we count our latitudes, is everywhere ninety degrees distant from the pole. But this pole is the pole of rotation, or the point at which the rotation axis pierces the earth's surface. It is not the pole of figure. Now, it is clear that the latitude of any observatory will remain constant only if the pole of figure and the rotation pole maintain absolutely the same positions relatively one to the other. These two poles are actually very near together, their distance apart being as small as fifty feet. Indeed, it was supposed for a very long time that they were absolutely coincident, so that there could not be any variations of latitude. But it now appears that they are separated slightly. And, strange to say, one of them is revolving about the other in a little curve. The pole of figure is travelling around the pole of rotation. The distance between them varies a little, never becoming greater than about fifty feet, and it takes about fourteen months to complete a revolution. There are some slight irregularities in the motion, but, in the main, it takes place in the manner here stated. In consequence of this rotation

of the one pole about the other, the pole of figure is now on one side of the rotation pole, and now on the opposite side, but it never travels continuously in one direction. Thus, as we have seen already, the sort of continuous motion required to explain the observed geological phenomena has not yet been found by astronomers.

Observations for the study of latitude variations have been made very extensively within recent years, both in Europe and the United States. It has been found practically most advantageous to carry out simultaneous series of observations at two observatories situated in widely different parts of the earth, but having very nearly the same latitude. It is then possible to employ the same stars for observation in both places, whereas it would be necessary to use different sets of stars, if there were much difference in the latitudes. Now the advantage of using just the same stars in both places is quite peculiar. It makes possible the determination of the small difference in latitude between the participating observatories in a manner which will make it quite free from any uncertainty in our knowledge of the positions on the sky of the stars observed. For, strange as it may seem, our star catalogues do not give us absolutely accurate results. Like all other data depending on fallible human observation, they are affected with small errors. But if we can determine simply the difference in latitude of the two observatories, we can discover from its variation the path in which the pole is moving. If, for instance, the observatories are separated by one-quarter of the circumference of the globe, the pole will be moving directly toward one of them, when it is not changing its distance from the

other one at all. This method has been in use for many years with good effect at the observatory of Columbia University in New York and at the Royal Observatory in Naples, Italy.

XI. EARTHQUAKES.

By William J. Hopkins, S. B.

The earth beneath us, which we are accustomed to regard as naturally firm and stable, is in reality in a state of continual vibration. Some of these motions, it is true, are so exceedingly slow and of such a gentle character, that records of past ages are needed to detect them. Others are so slight and faint that no impression is made on our imperfect senses, which note only shocks of exceptional magnitude and violence. The footfalls of an animal or the blows of falling raindrops may produce jars of the earth which can be detected by sensitive instruments, while the passage of a railroad train, or even of a street car, may shake the house, and such a catastrophe as the violent magazine explosion at Toulon would produce upon the adjacent country the effects of a moderate earthquake. These tremblings, of all degrees of violence, are so continuous that some investigations on the disturbance of gravity by the moon, undertaken some years ago, had to be given up. The earth vibrations overpowered the effects to be examined.

Of the slow and gentle movements of the earth referred to there are several. The continents are, in general, ris-

ing at a very slow rate, just about sufficient to make up for the wear of the land by the weather. Such an exceedingly slow motion as this can be detected only by referring to geological records, but there are other movements of a similar nature which, although very slow when reckoned by human standards, are geologically rapid. Parts of the eastern shore of North America appear to be now sinking at the rate of a foot or so in a century, while on other shores an uplifting is observable. Some coasts have within historic times made two or three oscillations of this character. The best known example is in the bay of Naples, where the land has sunk twenty feet or more, risen again by about the same amount, and is now again sinking at the rate of an inch or more a year, all since the beginning of the Christian era.

The imposition of a great glacial sheet of ice causes a sinking of the land, followed by a corresponding rise when the ice melts away. The unknown Antarctic Continent, under its burden of a sheet of ice, whose thickness is measured in miles, must be depressed by that burden many feet below the level it would assume if that ice were removed. Slight changes occur also, much more rapid but yet too gentle to be perceived except by the most delicate instruments. These swayings may complete their cycle in a few seconds or a few hours, and are perhaps due to changes in the weight of the atmosphere. They have been called pulsations.

In addition to these slow and gentle oscillations there are continual slight jarrings or tremblings of the earth, varying in frequency, from time to time. These can be detected only by such delicate instruments as the micro-

phone or the seismograph, which is an instrument designed to show by the records of pendulumlike oscillations the degree of violence, and the direction of earth movements. These tremors of the earth differ in no respect, except in violence, from earthquakes. They are most marked in regions subject to earthquake shocks and are most noticeable and continuous just before violent shocks.

CHARACTERISTICS OF EARTHQUAKES.

Strictly speaking, the term "earthquake" might be applied to any trembling or vibratory movement of the earth. It is customary, however, to apply the name to those shocks only which are severe enough to force themselves upon our attention, ranging in violence from the gentle shaking, which not every one notices, to the shock which destroys cities in a moment, with thousands of human lives.

The shock of the earthquake consists in the passage of a wave of pressure through the solid ground, just as a wave travels in water. Any sudden movement or concussion in the body of the earth's crust would be the source of one or more such waves. Rocks are somewhat elastic, some of them greatly so, although they differ much in this respect, according to their structure and nature. A sudden blow or concussion therefore sets up vibrations in the rocks, and these vibrations are sent outward in all directions, with velocities which may be different in different directions, or may even change at every point of the path, in accordance with the nature of the

rocks and soil through which they pass, and the relations of the rocks to each other. In these changes the waves of shock are reflected or turned aside, and may become, at a little distance from the source, very much confused. The wave from the same source might, therefore, reach any point at different times by different paths. Well recognized experiences of this kind are recorded in which both shocks came through the earth. In any case, there will be separate shocks through the earth, the water, and the air, arriving at different times, although produced by the same concussion. The air-wave causes the noise which sometimes accompanies the earthquake, and the water-wave, if the point is on the shore, accumulates until it may rush in, many feet high, and overwhelm the ruin which the previous land-shock had accomplished.

Earthquakes often appear to be capricious in their behaviour, certain small tracts being unaffected while the whole country immediately about is violently shaken. In some cases the shock travels outward in all directions from a centre, with some approach to equality, while in other cases it seems to pursue a well-defined track in a band or zone, without much departure from it laterally. This class of earthquake is typical of great mountain chains, and the best examples are the numerous great shocks which have affected the strip of country lying between the Andes mountains and the Pacific coast of South America.

The wave of shock constituting an earthquake has, at any point where it emerges upon the surface, a generally definite direction. Where accurate instruments are placed for the purpose, the direction of travel of the wave

is exactly recorded, and where there are no such sensitive indicators, the direction may be estimated approximately by the sensation and by the direction of the rents in the walls of the buildings or of the cracks produced in the ground. These rents or cracks are formed nearly at right angles to the line of travel of the wave, and by following the line back, the position of the source can be located at the intersection of several of such lines from different points. Following this method, it has been found that the source of earthquake shocks lies usually from two to twenty miles below the earth's surface, in a comparatively superficial portion of the solid crust of the earth. Elaborate studies of earthquake phenomena have been in progress for some years in Japan, where shocks are frequent, and where the method just described does not seem to apply, possibly because of the deflection of the lines of travel of the waves by peculiarities in the geological formation.

EFFECTS OF EARTHQUAKES.

The characteristic to-and-fro or up-and-down motion of an earthquake shock is too well known to need more than mention. A motion of the earth of an inch in extent would constitute a severe earthquake, while in those of most extreme violence, the motion is probably less than a foot. It is the suddenness of the shake which breaks buildings from their foundations, cracks their walls, and causes the great fissures sometimes seen in the ground. These fissures in the ground vary in width from the narrow cracks like those caused by the baking of the earth

A Javanese Village Destroyed by an Earthquake.

by the sun's heat, to great rents two feet or more wide and traceable for many miles. Such rents in the ground have been produced in peculiar cases, running for nearly 100 miles parallel to an adjacent mountain chain or to the course of a river. If these chasms are deep enough and long enough they may become the channels of streams and be worn by the action of the water into ravines and valleys.

A violent shock will shake loose rocks and earth from mountain sides and overturn unstable fragments left by the wearing of the weather. The existence of such monuments as pinnacled rocks, erosion columns, and frail natural bridges is, therefore, an evidence that the region in which they occur has been for many thousands of years exempt from severe shocks. Springs are temporarily disturbed, their flow being either diminished or increased, and the waters sometimes muddy or hot. Occasionally, too, nearly circular holes open in the ground and fill with water. It is supposed that these are due to the collapse of underground caverns or waterways.

In rare instances a violent earthquake has been coincident with a considerable permanent change in level of the land, the change in level probably being the cause of the shock. This was the case in the earthquake of 1822, in South America, when the coast of Chile, for a long distance, was raised three or four feet. In other cases, notably in a comparatively recent case, associated with a violent volcanic eruption, nearly the whole of large islands in Asiatic waters sank beneath the sea with thousands of the inhabitants.

CAUSES OF EARTHQUAKES.

While the phenomena and the superficial effects of earthquakes are very evident to us, the causes which produce these shocks are necessarily hidden, and can only be inferred or guessed. In general, however, it may be said that they are due to the gradual cooling of the earth. As the earth's substance cools, it contracts, and its diameter very slowly but surely becomes less. The outermost portions, which make up what is generally called the crust, have already gone through this process so far that the crust cannot keep up in contraction with the inner portions. The solid crust is therefore constantly pulled down by its own weight upon the continually lessening interior. As it is too large for the interior and does not fit, it must form wrinkles or corrugations. The larger wrinkles make up the continents and ocean beds, and the smaller ones constitute mountain chains and the smaller inequalities of the land.

This continent-building and mountain-building process has been going on since the world began and had any solid crust at all, is going on now, and will continue to go on so long as any contraction takes place.

The smaller wrinkles, forming ranges of mountains or hills, do not grow with such uniformity, and sometimes not so gently. A range of mountains which has been growing for ages may from change of conditions in the interior cease to grow. It may grow slowly and gently, or this slow growth may be interrupted by short periods of rest, during which the rocks partially withstand the

pressure upon them, followed by a sudden yielding, when the pressure increases beyond the limit of elasticity of the rocks. In this giving way of the rocks to form the comparatively sharp folds of mountains, the outer portions must slip on the inner portions, and rupture of the rocks must occur before such slipping can take place. Every break in the rocks, whether large or small, must give rise to an earthquake of some degree of violence, and the slipping of the jagged, broken portions past each other will cause further shocks. Occasionally the rent thus formed is filled with molten or semi-fluid rock, and the injection of this rock into the crack produces a shock. Along the ocean shores, where the older rocks have become exposed by the wearing of the weather and the waves, many such faults may be seen, the rocks sometimes riven in many directions and with almost countless cracks, every one of which in its formation must have been the source of an earthquake.

In addition to these less evident causes it is easy to see that violent volcanic action is likely to give rise to earthquakes, the explosion and rearrangement of matter beneath the surface setting up vibrations which make themselves felt in this way. Regions which are known to be volcanic would therefore be expected to be liable to earthquake shocks.

In North America there are records of earthquakes of some severity. In 1727, and the few years following, there occurred in Massachusetts a long series of shocks, at first affecting a comparatively large area, but soon becoming confined to the town of Newbury, which they continued to disturb for more than ten years.

In 1811 there began a series of shocks of extreme violence in a region on the Mississippi, with its centre not far below the junction of that river and the Ohio. These shocks continued for two years with such violence that an area measured in thousands of square miles was lowered several feet below its original level. Fortunately, this region was so thinly settled at the time that there were no costly buildings to be destroyed, and little or no loss of life was caused; but a repetition of such shocks now would probably result in the complete destruction of many cities and the loss of thousands of lives. Next in violence to this earthquake is that of Charleston, S.C., in 1886. This shock, attacking a region where no preparation had been made for such instability of the ground, caused widespread damage, wrecking parts of the city of Charleston. On the Pacific coast, where earthquake shocks are frequent enough to compel preparation for them and the adaptation of buildings to withstand considerable shaking, far less damage would probably be caused by a shock of equal violence. Indeed, it is interesting to note that in the shocks in San Francisco the tall buildings of the type known as "steel construction" have suffered much less than might reasonably have been expected.

THE GREAT LISBON EARTHQUAKE.

The most disastrous earthquake of which we have record was that of Lisbon, in 1755, and it may be of interest to give a few extracts from the account of an eyewitness. The account was probably written by a merchant who

lived in Lisbon at the time, and was published by Charles Davy in 1787.

A third violent shock followed the first two, and the river continued alternately rushing in and retiring. The tremors of the earth continued, with less violence, for days, making the more difficult examination of the ruins of the city, which was almost completely destroyed, with about 60,000 of its inhabitants.

"It was on the morning of this fatal day (November 1, 1755), between the hours of nine and ten, that I was set down in my department, just finishing a letter, when the papers and table I was writing on began to tremble with a gentle motion, which rather surprised me, as I could not perceive a breath of wind stirring. Whilst I was reflecting with myself what this could be owing to, but without having the least apprehension of the real cause, the whole house began to shake from the very foundation, which at first I imputed to the rattling of several coaches in the main street; but on hearkening more attentively, I was soon undeceived, as I found it was owing to a strange, frightful kind of noise under ground, resembling the hollow, distant rumbling of thunder. All this passed in less than a minute. . . .

" . . . In a moment I was roused from my dream, being instantly stunned with a most horrid crash, as if every edifice in the city had tumbled down at once. The house I was in shook with such violence that the upper stories immediately fell . . . and the walls continued rocking to and fro in the frightfullest manner, opening in several places. . . . To add to this terrifying scene, the sky in a moment became so gloomy that I could now distinguish no particular object.

. . . .

"In the midst of our devotions (on the river bank) the second great shock came on, little less violent than the first. . . . You may judge of the force of this shock when I inform you it was so violent that I could scarce keep on my knees. . . . Upon this, turning my eyes toward the river, which in that place is near four miles broad, I could perceive it heaving and swelling in the most unaccountable manner, as no wind was stirring. In

an instant there appeared at some small distance, a large body of water, rising as it were like a mountain. It came on foaming and roaring, and rushed toward the shore with such impetuosity that we all immediately ran for our lives as fast as possible; many were actually swept away, and the rest above their waist in water at a good distance from the banks. . . .

"One (master of a vessel) informed me that when the second shock came on, he could perceive the whole city waving backward and forward, like the sea when the wind first begins to rise; that the agitation of the earth was so great even under the river, that it threw up his large anchor from the mooring, which swam, as he termed it, on the surface of the water; that immediately upon this extraordinary concussion, the river rose at once near twenty feet, and in a moment subsided; at which instant he saw the quay, with the whole concourse of people upon it, sink down, and at the same time every one of the boats and vessels that were near it were drawn into the cavity, which he supposed instantly closed upon them, inasmuch as not the least sign of a wreck was ever seen afterward.

"With regard to the buildings, it was observed that the solidest in general fell the first. Every parish church, convent, nunnery, palace, and public edifice, with an infinite number of private houses, were either thrown down or so miserably shattered that it was rendered dangerous to pass by them."

POPULAR STUDIES IN ASTRONOMY.

POPULAR STUDIES IN ASTRONOMY.

I. THE SOLAR SYSTEM.

BY HENRY ALLEN PECK, Ph.D.
Sometime Professor of Astronomy, Syracuse University.

First Paper.

THE solar system consists of

1. A central body, the sun, incandescent and containing considerably more than 700 times the amount of matter contained in the remainder of the system.

2. A group of four inner planets—Mercury, Venus, Earth, and Mars—sometimes called the terrestrial planets, from their general resemblance to the earth, relatively small and dense and with few satellites.

3. A zone of minute bodies called asteroids, occupying a space between Mars and Jupiter, that nature seems to have intended for a planet she failed to provide.

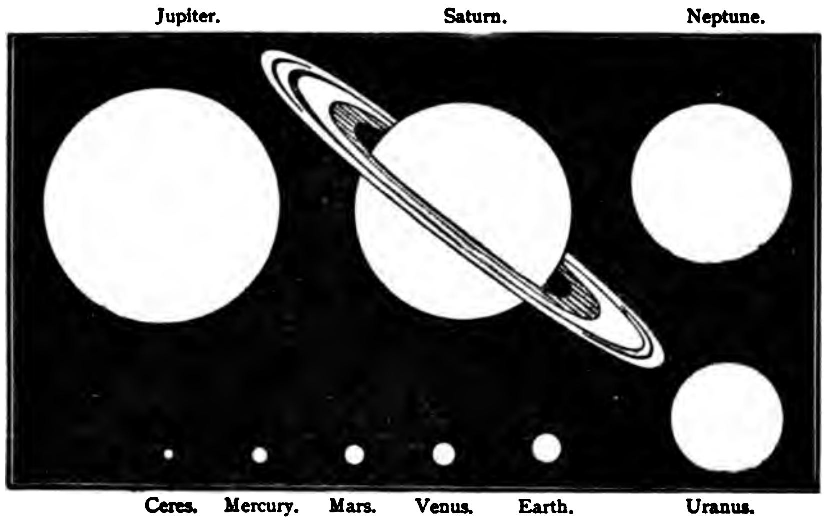
4. A group of four large planets—Jupiter, the giant of the system; Saturn, Uranus, and Neptune, of low density; with numerous satellites, and whose general physical

condition resembles more that of the sun than it does that of the earth, one of them, Saturn, being surrounded by a remarkable ring, and with its eight satellites presenting a picture of the whole system in miniature.

5. A series of transient members—the comets and meteors—whose number is unknown, and of whose presence we only become conscious when they approach the sun as comets or infringe upon the earth's atmosphere as shooting stars. Many of this transient class seem to have been added permanently to the system through the attraction of the larger planets.

Sir John Herschel has given an illustration which presents in a very intelligible form the dimensions of the system. Choose a level field, and on it place a globe two feet in diameter for the sun; Mercury will be represented by a mustard seed at a distance of eighty-two feet; Venus by a pea at a distance of 142 feet; the earth also by a pea at a distance of 327 feet; Mars by a small peppercorn, at a distance of 327 feet; the asteroids by grains of sand at distances varying from 500 to 600 feet; we may place a moderate-sized orange nearly one-quarter of a mile distant from the central point to represent Jupiter; a small orange two-fifths of a mile for Saturn; a full-sized cherry three-fourths of a mile distant for Uranus, and, lastly, a plum one and one-fourth miles away for Neptune, the most distant planet yet known.

A curious relation among the distances of the planets from the sun known as "Bode's law" is usually given in astronomical text-books, though it is well to remember that it rests on no known physical fact, and has no value except as an aid to memory. Add 4 to each of the num-



Relative Sizes of the Planets.

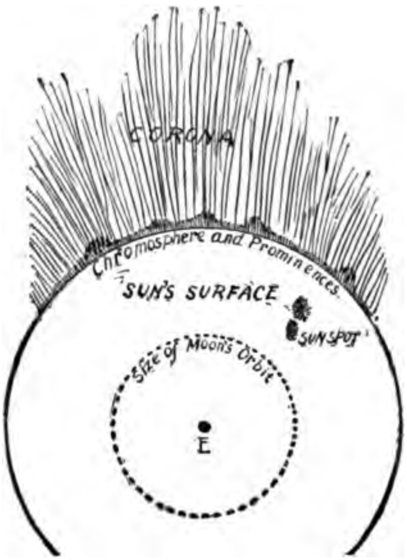
bers 0, 3, 6, 12, 24, 48, 96, 192, 384, and, if the distance of the earth be assumed to be 10, the results will quite nearly represent the distances of the planets from the sun with the exception of Neptune, as may be seen from the following table, Ceres, one of the asteroids, being taken to represent that group of bodies:

	Bode's Law.	True Distance.
Mercury	4.00	3.87
Venus	7.00	7.23
Earth	10.00	10.00
Mars	16.00	15.23
Ceres	28.00	27.66
Jupiter	52.00	52.03
Saturn	100.00	95.39
Uranus	196.00	191.83
Neptune	388.00	300.37

Many other curious analogies may be found in some of the larger works on astronomy, none of which have attained such fame as Bode's law.

Both on account of its size and importance to us, the sun has been more studied than any other body of the system. It is the centre of life as well as of light and power. Nearly all the forms of energy with which we are familiar may be traced to it, and the ancients who worshipped it seem to have dimly recognised its importance in the economy of nature. Its distance from the earth, 93,000,000 miles, is taken as the unit of measure in determining the distances inside the solar system, much as we use the foot and yard as the standard of measure in daily life. Its diameter is 866,400 miles, a number so vast that to properly estimate it we must have recourse to illustra-

tions. If we could consider it as a hollow ball with the earth at its centre, not only could the moon revolve around the earth within it entirely undisturbed, but there might be another satellite, also revolving, at nearly double its distance. Its volume is over 1,300 times that of the



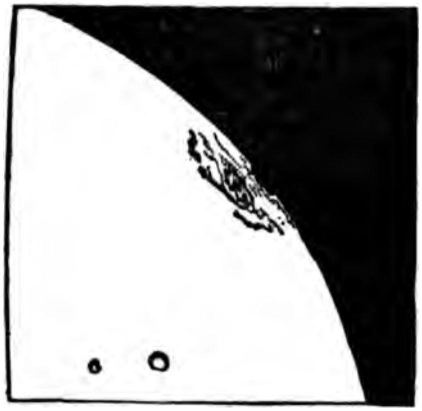
COMPARATIVE SIZES OF SUN AND EARTH.

earth, but the amount of matter composing this huge mass is by no means in the same proportion, since its average density is only about one-fourth that of our planet. On the earth a body falls 16.1 feet the first second, while on the sun it would have a velocity of 27.4 times as great. It is a sphere, self-luminous and of very high temperature. But while it sustains such important relations to us, it is well for us to remember that it is but

one among a great host of similar bodies that exist in space, and differs in no essential particular, so far as we can judge, from the thousands of stars. Arcturus is quite possibly 100 times its diameter and gives out 6,000 times as much light, while the pole star, by no means one of the brightest in our northern heavens, probably exceeds it in a ratio of 200 to 1 in light-giving power.

The study of the sun may be conveniently divided into that of the central nucleus, the photosphere, the chromosphere, and the corona. Of the nucleus or body of the sun nothing can be stated except in the most general terms. No eye or instrument has ever penetrated beneath the dense shell of vapour that hides it from our view. It must grow more and more dense as we approach the centre and be the seat of those activities which show themselves outwardly in the form of light and heat. The immense radiation that has been taking place for so many ages, and is to-day as undiminished as in remotest historic times, can best be explained by the theory of Helmholtz. That it cannot arise from combustion in the ordinary sense of that term is evident, since a solid globe of anthracite of the same size would have been exhausted within the comparatively brief time of recorded human history. If a body is suddenly brought to a state of rest from that of rapid motion, as when a cannon ball strikes a steel plate, its motion is transformed into sensible heat and light. The same *amount* of heat will be produced if its motion is lost by the projectile being more gradually brought to rest by the resistance of friction, though its production may be extended through a greater space of time. Helmholtz supposed, and to-day the theory is

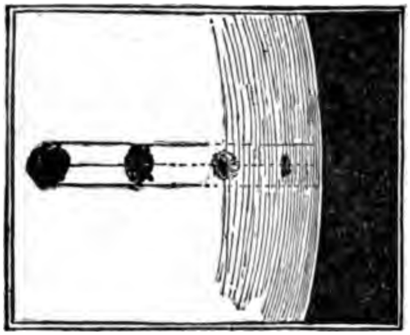
quite generally accepted, that the gradual shrinkage of the matter composing the body of the sun would produce sufficient friction among the particles as they drew closer together to account for the greater share of its light and heat.



SUN SPOT SEEN AS A NOTCH.

The photosphere is the part of which we become conscious when we view the sun either with the naked eye or with a telescope. It is the outward shell surrounding the intensely heated interior—if we dare speak of such a body having a definite outer surface. When viewed with sufficient optical power under favourable circumstances, it appears mottled or blurred, and not of a uniform white surface. The centre will be found brighter than the edges, because the rays from the centre of the disk pass through a lesser depth of solar atmosphere than do those from the edge. Here and there may be found patches brighter than the remainder, but more striking will be

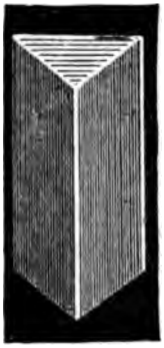
the dark spots. The brighter patches, or faculæ, are elevations, while on the other hand the spots are depressions. A few minutes' observation will show that the spots are not uniformly dark, but that the general surface shades into a dark central nucleus. If the spot is near the edge, the contrast between it and the bright faculæ in the



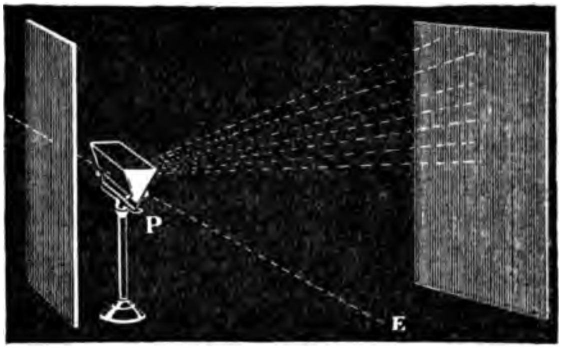
CHANGE OF FORM IN SUN SPOTS OWING TO THE SUN'S ROTATION.

neighbourhood is often quite marked. The spots vary in size from those scarcely visible to those so large that they can be seen with the naked eye, properly protected with a bit of neutral tinted or smoked glass. They are found both singly and in long lines or curves stretched across the disc. Sometimes they undergo very rapid changes, and again the same spot may be recognised for several months. They are never seen at a greater distance than forty-five degrees either side of the solar equator, and for the most part are confined to belts between five and thirty degrees north and south latitude. From their apparent motion across the disc, the rotation of the sun on

its axis and the direction of this axis in space may be estimated. This period of rotation is about twenty-five and one-fourth days, although spots at different distances from the equator yield different values. Spots half-way between the equator and pole show an apparent rotation of over twenty-seven days. The cause of this acceleration at the equator is unknown.



PRISM.



LIGHT PASSING THROUGH A PRISM.

The chromosphere, a gaseous envelope surrounding the sun, and comparatively shallow, is studied by the spectroscope. Every one is familiar with the fact that if a beam of sunlight is allowed to pass through a prism of glass and fall on a screen or white wall the light becomes resolved into its so-called primary colours. If the precaution is taken to have the light enter through a fine slit before it falls on the prism, the band of colours will be found to be crossed with fine dark lines—the Fraunhofer lines of the physicist. A spectroscope is a combination of slit, lenses, and prisms so arranged as to pro-

I. THE SOLAR SYSTEM.

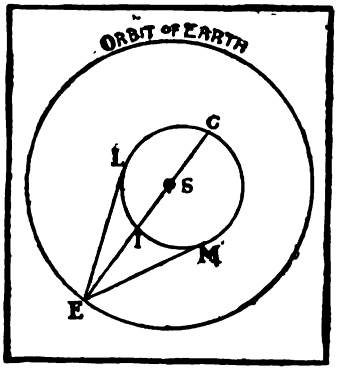
BY HENRY ALLEN PECK, Ph.D.
Professor of Astronomy, Syracuse University.

Second Paper.

FROM the earliest times the ancients distinguished between the planets and fixed stars. They observed that the former maintained the same relative position with regard to each other, while the latter appeared, first in one quarter of the heavens and then in another. While at first there might appear to be no law governing these apparently irregular motions, yet it finally dawned on successive generations of observers that these motions bore some relation to the mutual positions of the sun and the earth. Two planets, Mercury and Venus, were always to be found near the sun, the latter never more than forty-seven degrees distant, but alternately appearing as an evening star after the setting and as a morning star before the rising sun. The other planets, Mars, Jupiter, and Saturn, all that were known to the ancients, appeared to have no such limitations, but, alternately advancing and retreating, tracing various curious loops as they travelled among the fixed stars, they worked their

way eastward, and in the course of years gradually made the circuit of the heavens, the path they described, however, always following somewhat closely the annual track of the sun among the fixed stars.

Without entering into the details of the cumbrous systems by which they attempted to explain these motions, we may at once consider the Copernican theory as modified by Kepler, which affords a simple and true explanation of all the phenomena involved.



The planets, including the earth, revolve around the sun in elliptical orbits, of which the sun occupies one focus. Two of these planets, Mercury and Venus, have orbits whose radii are shorter than that of the earth, and they consequently lie wholly within it. The orbits of all the other planets lie wholly outside that of the earth. The velocities of the planets in their orbits are less the more remote they are from the sun. Consequently the first two planets appear to vibrate from one side of the sun to the other, while the

remainder retreat and then advance, according as the earth is ahead of or behind them.

A consideration of the accompanying diagram will make the foregoing clear, so far as it relates to Mercury and Venus. Suppose at first the earth still at E, and a planet travels around the sun on the inner circle in a direction opposite to that of the hands of a watch. As viewed from the earth it will move apparently to the right from I, the point at which it is in a straight line with the sun to M, from which point, after a short pause, it will apparently retreat to the left while pursuing its course to L, when it will again pause and then resume its journey to the right as it returns to I. If now the earth be considered to move in the same direction in its orbit as the planet, but with a less velocity, no change will result in our main conclusion, but the rate of apparent motion of the planet will vary at different points in the orbit according as both bodies are proceeding in the same or opposite directions. At M the planet appears high in the western heavens as the evening star, while the corresponding morning phase is at L. If the planes of the orbits were the same, these apparent motions would be in a straight line, but since the orbits are inclined to each other, loops are formed.

The discovery by Galileo that the inner planets have phases like the moon, whereby sometimes they appear as thin crescents and at other times as full round discs, proves that they shine by means of reflected sunlight. If they shine in this manner, only that portion which is turned toward the sun can be illuminated. Returning to the diagram, it can be readily seen that when at C the

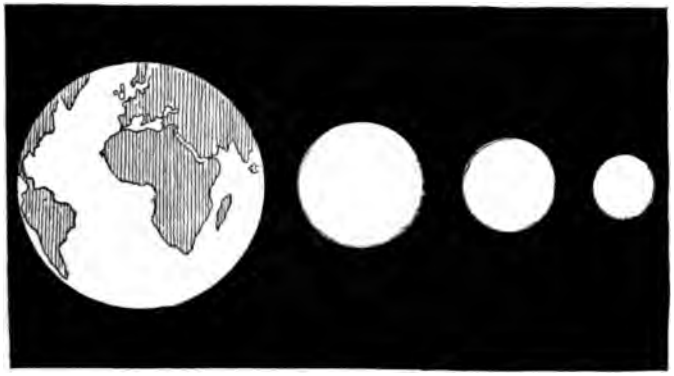
THE TRANSIT OF VENUS—LAST CONTACT.

From a photograph made at Whangaroa, Chatham Island, 1874.

same surface is turned toward the sun and earth, while at I the illuminated portion is turned away from the observer. At M and L half the illuminated disc will be visible. Between these points and I the planet will appear brighter than near C. Although at this time it is only a thin crescent, its less distance, and consequently greater apparent size more than compensate for the less surface seen by us. Venus will be brightest thirty-six days before and after it passes I. The outer planets can never appear as crescents, though Mars may attain a phase similar to the gibbous moon.

The planets as a whole have several features which argue a common origin with the sun, but the group inside the ring of asteroids have certain other features which distinguish them from the outer group, and which have led many thinking astronomers to suppose that they may be older as regards their existence as separate bodies. All the planets, so far as it can be absolutely proved, have a common direction of rotation, that of the sun on its axis. The periods, however, are various, and the more distant and larger have the shorter time of rotation. Late observations seem to confirm the view that Mercury and Venus always present the same face to the sun, probably for the same reason that only one hemisphere of the moon is ever seen by us. Mars and the earth are similar to each other in this as in many other respects, while the giant outer planets have periods less than half that of the earth. The planes of the orbits are essentially that of the earth, so that they are never seen in the sky more than eight degrees from the sun's path, thus fixing the limits of the zodiac. The eccentricities of the orbits are quite slight,

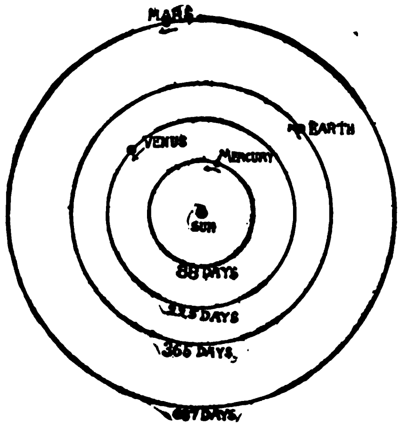
except in the case of Mercury and Mars, that of the former being more marked. The planet approaching the nearest to the earth is Venus, her distance under favourable circumstances being only about a quarter that of the sun. In many features this planet deserves its name of "twin" as regards the earth, although we know less of



COMPARATIVE SIZES OF EARTH, MARS, MERCURY, AND THE MOON.

its surface than of the more distant Mars. The times of revolution around the sun vary from eighty-eight days for Mercury to 165 years for Neptune, and the distances from 36,000,000 miles for the former to 2,790,000,000 for the latter. The apparent difference in size of the nearer planets is very large, according to their position relative to the earth. Their diameters range from 3,000 miles for Mercury to 87,000 miles for Jupiter, and the density of this planet and others of the outer group is so slight that their swift rotation has produced an appreciable ellipticity of figure. The number of satellites varies from one in

the case of the earth to eight for Saturn, but it must constantly be borne in mind that others may be present, while unknown to us. From time to time it has been supposed that traces of other planets have been found, whose orbits lie within that of Mercury or beyond that of Neptune.



THE ORBITS OF THE FOUR INNER PLANETS.

No planet has ever aroused more popular interest than Mars. We seem to see here a picture of conditions in many regards similar to those with which we are familiar. Shadings are observed which have been referred to the effect of land and water contrasts. Changes hard to explain occur from time to time. About each pole is a cap, apparently like the snow-cap about the north and south poles of the earth, and these caps increase and decrease according as the pole happens to be exposed to the rays of the sun or is turned from that body. Lines crossing the surface in all directions, and called canals, have been

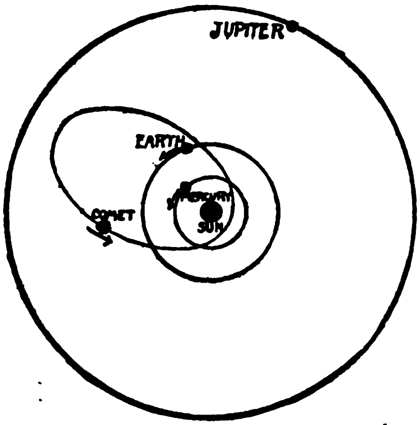
observed, and these lines often undergo surprising transformations. In no case, however, is it more necessary to carefully discriminate between observed fact and unauthorised speculation than in our treatment of this planet.

While Jupiter is the planet that affords the most interest to the observer armed with only a small telescope, yet if one has sufficient optical means at his disposal, next to the sun and moon Saturn is the most magnificent object of the solar system. As has been well said, its unique ring and splendid retinue of satellites have been left in their present condition to teach us how the solar system was formed. The outer diameter of the ring is 173,000 miles, but the thickness is quite inconsiderable in comparison. It is undoubtedly composed of thousands of small satellites, each so minute that they only reflect the sunlight as a whole.

JUPITER AND THE EARTH COMPARED.

Occasionally the appearance of a great comet arouses popular interest in these bodies, and causes inquiry as to their origin. It is well to remember, however, that the

number of those seen by the naked eye is only a small fraction of those that actually exist, or even of those that are known to astronomers. It is somewhat rare that at least one is not visible in the telescope, and often several are visible at the same time in different quarters of the heavens. While their phenomena have been made the subject of much patient investigation, there is much yet to be learned with regard to them. They seem to repre-



THE ORBIT OF ENCKE'S COMET.

sent the waste of the system, the matter left over when the different bodies of the universe were formed, and they float round through space, first under the influence of one star and then of another. That the greater share originate at so great a distance from the sun as to be practically only transient members of the solar system, is shown by the form of their orbits. That they are bodies of inconsiderable density and contain a very small amount of matter, in spite of their often enormous size, is evident

from the fact that they are always greatly disturbed whenever they approach a planet, but thus far not the slightest reciprocal influence upon such a planet has ever been observed. Unlike the planets, all of whose motions are in practically one plane and in one direction about the sun, they approach that body indiscriminately from all points and in general depart to return, if ever, only after the lapse of centuries. Nearly 1,000 have been recorded, but only a very small percentage of these are known to have been seen at a subsequent reappearance. A comparatively small number pursue definite closed orbits, but all of these orbits bear such peculiar relations to the larger planets, that it seems impossible to escape the conclusion that they have been captured by them and that their original orbits have been transformed by the attraction of these planets. From the time a comet is first seen it undergoes quite startling transformations as it approaches the sun and then recedes from it. While the sequence of these changes is rarely the same, and any one of them may be wanting in a particular comet, yet there is a typical life history to which they all in a greater or less degree conform. When first seen, a comet appears as a pale ball or cloud of diffuse, nebulous light, without any particular structure. As it approaches the sun, a star-like nucleus will develop within this cloud, from which jets will be thrown off toward the sun, and these, turning backward as if repelled by it, form a series of envelopes terminating in the tail, often a magnificent object stretching millions of miles in a direction opposite the sun. As the comet recedes, pushing its tail ahead of it, these activities cease, and it fades from sight as structureless as at first. Per-

haps no popular impression with regard to comets is so erroneous as that which regards the tail as formed after the analogy of the steam left behind by a locomotive. The true explanation seems to be that while the comet body is attracted to the sun by gravitation when it approaches near enough to have part of its surface vapourised, these vapours are repelled by some as yet unknown force proceeding from the sun.

II. THE SUN.

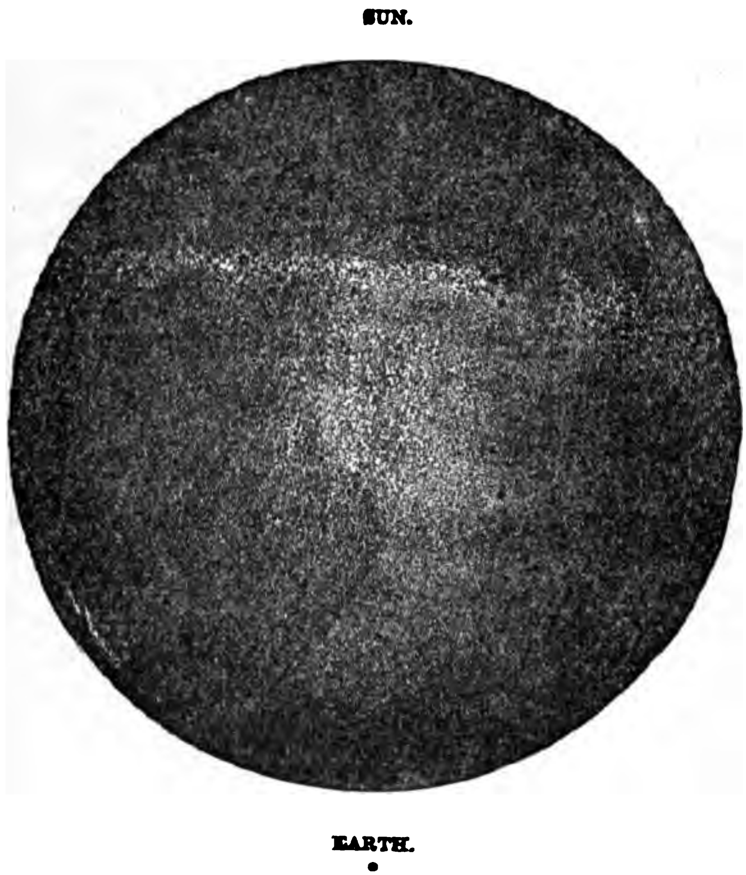
By George Cary Comstock, Ph.B., LL.B.

Professor of Astronomy, University of Wisconsin.

First Paper.

Considered alone, and without reference to human interests, the sun must be set down as only a commonplace member of the innumerable host of stars, differing in no essential respect from hundreds of his fellows, many of which really surpass him in size and appear less resplendent only because they are farther from us. But with respect to human affairs, the welfare and the continued existence of mankind, scientist and layman alike recognise his preëminent rank as the source and support of nearly every form of energy and every type of life upon the earth.

The astronomer who approaches at first hand the study of this splendid orb may fairly enough be likened to the detective who is charged with investigating a crime and finding out a criminal. Just as the traces left behind—the bloodstain, the torn fabric, the footprint—are to be united into a theory which shall account for their presence and for every other visible circumstance connected with the crime, so the isolated facts and unconnected observa-



MAGNITUDE OF THE SUN COMPARED WITH THE EARTH.

tions pertaining to the sun are to be pieced together into a consistent theory of what the sun is, what he does, and how he does it. An account of how the solar machine is constructed and how it runs may be regarded as our ultimate goal, but one which at present is far from being attained. We commence to gather our material for such an account, not by looking at the sun with a telescope or photographing it with a camera, but by an appeal to the astronomers who have sought to weigh and measure it and to analyse its chemical structure. We need statistics, facts, and figures in order to appreciate and to understand what the telescope has to show; and let it be emphasised that these statistics furnished by the astronomer are not vague guesses at the truth, but are much more accurate, proportionally, than are the weighings and measurings of ordinary life.

When the suspension bridge was built across the Niagara River, just below the Falls, it was necessary to measure in advance the width of the impassable gorge, and the ordinary methods of the surveyor's art, which proved sufficient for this purpose, would equally suffice to measure the sun's distance from the earth if that distance were no more than a few thousand miles. But in fact the surveyor's method breaks down absolutely when applied to the sun, and its failure shows that his distance from us is something enormous. It is only by using a nearer planet as an intermediary and by greatly increasing the size and accuracy of the instruments employed that the surveying method has been made to apply by a circuitous route to the case in hand, and as the result of the latest and best determination we may say with entire confidence that if

a straight line were drawn from the earth toward the sun for a distance of 92,900,000 miles, its end would lie somewhere inside the sun's circumference, but whether on the one side of the centre or the other is still uncertain. The books abound with illustrations intended to render this inconceivably great number more apt of comprehension, but a single one of these must suffice. If we adopt the traditional chronology of the Bible, and suppose that Adam and Eve, after their expulsion from the garden of Eden, seeking a new home, turned their steps toward the sun, and from that time to this have travelled ceaselessly thither on foot, at the rate of forty miles per day, they would not yet have reached their destination, but would have approached so near to it that a few additional centuries would end their journey.

This distance of the sun from the earth is the key to all our required statistics, and from it we learn by mathematical methods, which, although simple, would be out of place here, that if we consider the sun to be a globe, as its appearance indicates, its circumference is more than 100 times as great as that of the earth—*i.e.*, the shining face of the sun, which the eye can compass at a glance, has a circumference of 2,750,000,000 miles and a surface whose area is equal to that of 6,000 bodies like the earth. These dimensions suggest that the sun should be far more massive than the earth, and such is in fact the case, although not to so great an extent as might have been expected, for if the material of which the sun is made were of the same density on the average as that of the earth, then its mass would be more than 1,000,000 times that of the earth, while a careful comparison of the inten-

sity of the attractions exerted by the earth and sun upon another planet, such as Venus, shows that its mass—or weight, in popular language—is in fact only 329,000 times as great as that of the earth. Here is a most significant fact to be worked into our account of the sun, since it shows that the material of which it is composed, bulk for bulk, is only about one-quarter as dense as is the stuff of which the earth is made. To use a more familiar comparison, the material of the sun is on the average about as dense as asphalt or anthracite coal, but it must be borne in mind that owing to the great mass of the sun the weight of a cubic foot of its material is about twenty-seven times as great as the weight of a cubic foot of coal, although if the coal were transported to the sun it would there weigh as much as an equal bulk of the solar material.

A little reflection will show that this increased weight of bodies upon the sun produces upon all the lower lying strata, which have a load to carry, a very much greater pressure than in the case of the earth's strata, and as it is common experience that increase of pressure produces greater density in the material which is squeezed, we see at once that this low density of the solar material where we should have expected a greater one corresponding to the pressure, indicates one of two things—either the sun must be made of very different and lighter material than that of the earth, or this material, if of the same kind as that of the earth, is exposed to some peculiar circumstances which profoundly change its density. As we shall see later, there is abundant reason for believing that on the whole the sun and earth are built up from much the same chemical elements, the same kind of stuff, and

we must therefore adopt the second of our alternatives, that the physical conditions in the sun are widely different from those at the earth's surface. One kind of difference in these conditions we shall be quite prepared to find, since the most ordinary observation shows that the sun must be a hot body in order to produce the scorching effects of which his rays are capable, even at our distance from him, and we note that this circumstance of high temperature is just what is needed to explain his low density, since here our commonplace experience assures us that in general raising the temperature of any substance expands it and makes it less dense.

Just how much the earth would need to be heated and expanded in order to reduce its density to a level with that of the sun is a question too complex to be entered upon with profit, but we may rest assured that it would be measured in thousands of degrees, and an even higher temperature must be expected upon the sun, since a greatly increased force of gravity and increased weight is there to be overcome by the expansive influence of the heat. It is not difficult to show by direct experiment that the temperature of the sun is indeed measured in thousands of degrees, for if its rays be concentrated by a powerful burning-glass, their effect is sufficient to melt and vapourise the most refractory substances, such as firebrick or the diamond, and the principles of optics show that the temperature thus produced at the focus of the burning-glass, certainly more than 3,000 degrees, must be considerably lower than in the source from which the sunlight came. The most reliable investigations of the sun's effective temperature give about 18,000 degrees Fahrenheit

as a probable value, but for the present this number must be accepted with considerable reserve.

To justify our statement that the sun is composed of chemical elements like those of the earth, we must briefly consider the spectroscope, which is an instrument in common use among chemists for making their analyses. The substance to be analysed is heated to a white heat—to incandescence, as it is called—by placing it in a flame or by passing a powerful electric current through it, and a ray of light emitted from the glowing substance received by the spectroscope and passed through a transparent prism of glass is drawn out by the glass into a ribbon of light, showing in regular succession from end to end the colours of the rainbow, but with countless minor peculiarities of colour, depending upon the nature and condition of the substance from which the light came. It is these peculiarities which, when once learned and understood, enable the chemist to say at a glance that magnesium or iron or sodium is present or is not present in the substance which furnishes the light.

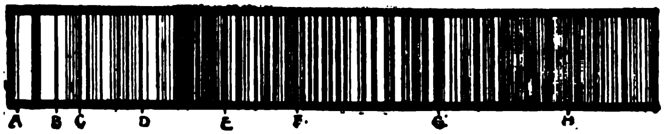
The peculiar advantage of the spectroscope to the astronomer lies in the fact that it makes little difference whether the instrument is placed close to the substance which is to be analysed or is set down millions of miles away from it. The peculiar nature of each chemical element is stamped upon the light which it emits and goes with the light as far as it travels, so that sun and stars alike may be analysed by means of the same principles which, according to the chemist's experience, hold good in his laboratory. Some of the more important of these principles are as follows: If the substance which emits the

light is a solid body—*e.g.*, the carbons in an arc lamp—it will furnish in the spectroscope a perfectly continuous ribbon of light, called a spectrum, which shows every gradation of colour, from the deepest red to the extremest tone of violet that the eye can detect. On the other hand, if the substance to be analysed is an incandescent gas, such as occupies the space between the carbons of an arc lamp, for example, its spectrum will consist of only a few narrow samples cut out here and there from the ribbon of coloured light and separated by dark spaces in which the light is entirely suppressed. A picket fence, in which the pickets are set so close together as actually to touch each other, and are painted red at one end of the fence and violet at the other end, will fairly represent the continuous spectrum given by the light from a solid body; while the same fence, after most of the pickets have been knocked off, leaving only here and there one as a sample colour, will represent the kind of spectrum given off by a gas. Each individual sample is called a line of the spectrum and each chemical specimen has its own characteristic set of lines, which may be few or many, strong and bright, or faint and hard to see.

The difference between the spectra of solids on the one hand and gases on the other seems to come from the different conditions in which their constituent molecules are placed, the molecules of a piece of iron, for example, being crowded so close together that they interfere seriously with each other in the vibrating motion which accompanies that high temperature, while when the iron is vapourised by excessive heat those same molecules are so far separated as to produce little interference one with

another, and to furnish a very different kind of spectrum. We find, therefore, that whenever the molecules are packed close together, as in a solid or liquid, even in a gas which is very much compressed, the spectrum is a continuous ribbon of light which conveys no information, except that the molecules are thus crowded, while the line spectrum speaks as unmistakably for a gaseous state and freedom of motion.

When sunlight is examined in the spectroscope, it furnishes a continuous spectrum, indicating a compressed



PRINCIPAL LINES OF THE SOLAR SPECTRUM.

state of the molecules, which is what we should naturally expect, since we have already seen that its density is comparable with that of hard coal. But we also find something more, for across the continuous spectrum are drawn a great number of narrow black lines—as clean and sharp as if made with a fine pen—the so-called Fraunhofer lines, which are shown in the foregoing figure, where some of the more prominent ones are marked A, B, C, etc. A lies at the extreme red end of the spectrum, while G and H are in the violet. These lines are nothing else than parts of the spectrum at which the light has been cut out, absorbed, before it reached the spectroscope, and two of the most important principles of the spectrum analysis were discovered half a century ago from a study of those lines

in a laboratory—namely: This absorption of light is produced by a layer of gas less heated than the source from which the continuous spectrum comes, and interposed between that source and the spectroscope; and this gaseous veil absorbs from the light sent to it exactly those sample colours which it would itself emit if incandescent, so that the Fraunhofer lines, which the cooler gas produces, are a perfect picture; a negative of the bright lines which would compose its own spectrum.

The presence of the Fraunhofer lines in the solar spectrum therefore indicates a gaseous screen placed between us and the sun, and it is easy to recognise that in part, at least, this screen must be our own atmosphere, which contributes its quota to change the sun's spectrum. This contribution is, however, an exceedingly small one, and by far the larger part of the Fraunhofer lines are due to an atmosphere surrounding the core of the sun, an envelope whose chemical nature may be ascertained if we can identify the Fraunhofer lines with the spectral lines given off by our own terrestrial elements. Now, this is an exceedingly difficult problem, which has not yet been completely dealt with, although in part it has been solved. The exact correspondence of a number of lines in the spectrum of iron, for instance, with lines in the sun's spectrum, cannot be the result of chance, but points rather to the existence of iron in the sun, and other terrestrial elements are to be compared in the same way. The great number of these lines—there are thousands upon thousands of them—indicates a composite atmosphere made up of many different elements, whose lines in the spectrum must be sorted out and distinguished one from another,

much as if it were required to sort out from a composite photograph the several faces of which it is made up. But, difficult as is the problem, it has been at least partially solved, and about one-half of our terrestrial elements, mainly the metallic ones, are shown to be present as gases in the sun's atmosphere. It must not be inferred that elements whose lines we do not find in the sun's spectrum are absent from the sun, but only that spectroscopic proof of their presence is more difficult to obtain.

II. THE SUN.

By George Cary Comstock, Ph.B., LL.B.

Professor of Astronomy, University of Wisconsin.

Second Paper.

We are now to take up a consideration of the things to be learned from a study of the sun's appearance as seen or photographed with the telescope, bearing in mind, as a guide to understanding the things seen, the substance of the preceding article—namely, that the sun is an enormously large and distant body upon which we shall expect to see only those great features whose extent is measured in hundreds of miles, and where all minor details must be lost to view, no matter how powerful the telescope; that it is made up of much the same chemical elements as the earth, and that these elements in the outer parts of the sun exist as a gaseous envelope, surrounding the inner and denser parts, which must be very much more compressed and dense than are the outer gases; that these central portions are heated to a temperature far beyond the measure of any terrestrial objects, and are so hot, indeed, that the common phrase which likens the sun to a ball of fire seems ludicrously inadequate, since

fire could not exist at the temperature of the sun, the chemical processes of combustion being possible only at a far lower temperature.

To examine the sun with a telescope of course requires some special provision for protecting the eyes against an excess of light and heat, and this provision may be made in several different ways, all involving the same general principle of wasting most of the light which comes to the telescope and admitting to the eye only a selected fraction of it. But, however the telescope may be arranged, a view of the sun through it is almost always disappointing to the inexperienced visitor, who usually expects to see at one glance the whole face of the sun greatly magnified. This is impossible, since the greater the magnifying power the less is the area that can be seen at any one time, and it is only by piecing together views separately obtained that a complete picture of the sun can be had under even a moderate magnifying power.

In such a picture the round, shining disk of the sun—the photosphere, as it is called—seems at first as barren of all details as is a sheet of white paper, save that here and there its monotonous uniformity is broken by a black patch, which may be a mere dot or an area of considerable extent and irregular outline, or, quite as likely, a jumble of spots of the most varied sizes and shapes. Upon closer examination a large spot will usually be found to consist of a darker nucleus, with an irregular border intermediate in brightness between it and the adjacent parts of the photosphere. This border, which is called the penumbra of the spot, oftentimes presents a very delicate and complicated intertwining of filaments, which for the most part

SUN-FLAMES 142,000 MILES HIGH—EIGHTEEN TIMES THE EARTH'S DIAMETER.

extend radially outward from the nucleus, but are sometimes disarranged beyond all semblance of order. If a spot happens to be found very near the edge of the sun, a close scrutiny of the adjacent regions will often show spots of a different kind, slightly brighter than the surrounding photosphere and in shape resembling crooked fibres. These are called faculæ, and appear to be in some way related to the dark spots, for they occur in connection with them wherever spots are found, at the centre of the disk as well as at the edge, only they are not so easily seen at the centre, since the background furnished by the photosphere is there brighter than at the edge. The photosphere itself, when carefully examined, seems of more complicated structure than at first. Instead of a smooth and uniform surface, it is more like an assemblage of small but brightly illuminated summer clouds, separated by darker lanes and rifts, and there is reason for believing that these cloudlike regions furnish the greater part of the light and heat that come from the sun.

The casual visitor at the telescope should not expect to see much beyond the features thus named, but they will abundantly repay repeated examinations. Thus a group of sun spots will rarely look alike on two different days: some of the spots vanish from sight and new ones appear; a large spot may break up into smaller ones, and even a few hours may suffice to completely change the appearance of a single spot. From day to day the spots slowly change their position upon the sun's face, drifting across it always in the same direction and sometimes disappearing behind one edge of the sun to reappear a fortnight later over the opposite edge. This continuous drift of

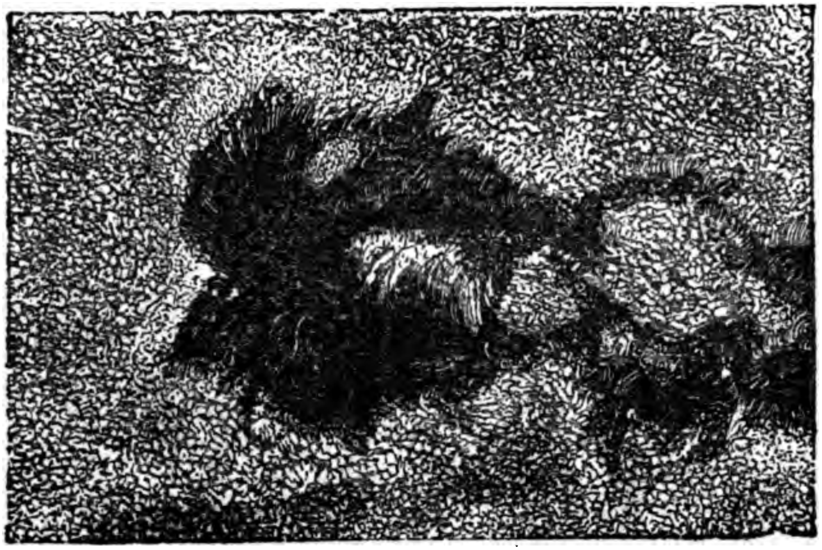
the spots can have only one meaning—that the sun, like the earth, revolves about an axis, so that in the course of some twenty-seven days it presents every face in succession toward us just as in each twenty-four hours every meridian of the earth is turned toward the sun. The sun, therefore, like the earth, has poles where its axis meets the surface, and an equator midway between these poles, but, unlike our terrestrial geography, it has no continents and oceans, no fixed and permanent features of its surface to be set down upon a map. All is flux and change; the spots and faculæ come and go and leave no abiding trace behind, and every other mark upon the photosphere is equally transient. But amid all this change traces of law and order, of a regular working of the solar machine, are to be found. The spots do not occur at haphazard upon every part of the sun, but are strictly limited to a rather broad belt on each side of the sun's equator, extending about half-way to the poles, and within this region they are not equally numerous at all times, but come and go in rather irregular order, from seasons of abundant spots to seasons of extreme poverty and back again to abundance, in a period of about eleven years on the average—the famous sun-spot period, of which more hereafter.

The study of the spots and their movements brings to light one remarkable feature of the sun's mechanism. Throughout the entire width of the sun-spot belt, and probably to the very poles themselves, the farther we recede from the equator the longer is the time required for a spot to make its apparent circuit about the sun and return to its starting point, so that, unlike the earth, which turns as one piece, like a solid body, each different

zone of latitude upon the sun has its own peculiar rate of motion, by reason of which two spots in slightly different latitudes tend to drift slowly apart like two ships upon an ocean in whose surface different currents are flowing.

Thus far we have been dealing with things which may be seen upon the sun with its visible portions, which we must now admit are only the smaller part of its bulk, although, indeed, they make up by far the larger part of its substance. There are parts of the sun invisible under all ordinary circumstances on account of the dazzling brilliancy of the photosphere, but which become visible, and even conspicuous, when these rays are cut off by the moon during a total eclipse. Then the entire edge of the sun is seen to be encircled by a narrow but brilliant fringe of crimson light, out of which spring here and there prominences like projecting tongues of flame, frequently of irregular and fantastic shape, and stretching upward to heights which are measured in tens of thousands and even hundreds of thousands of miles. Some of these curious appendages are shown in the cut, which represents a part of the edge of the sun viewed during an eclipse. The shell of crimson light out of which these prominences rise is called the chromosphere, and it is here and probably in its very lowest layers that occurs that absorption of light coming from the photosphere which produces the Fraunhofer lines of the solar spectrum. The fact that these lines are produced in the spectrum shows that the chromosphere must be a gas cooler than the photosphere, although itself at a temperature enormously high compared with terrestrial standards.

The rapid changes of appearance which the spots pre-



Sun Spot (December, 1873).
(From a drawing by Langley.)

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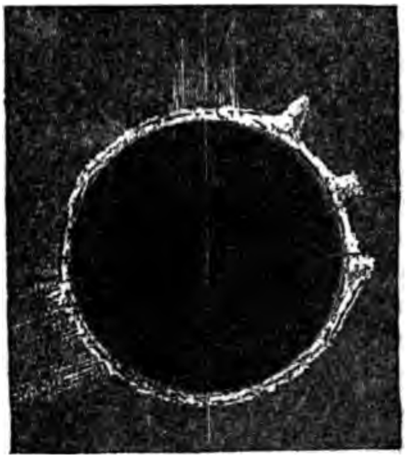
sent have prepared us to find in the chromosphere and the prominences something of the same mobility, and in fact they are formed and refashioned and blotted out from sight sometimes with a rapidity which can only be compared to that of explosions produced by something more potent than gunpowder or dynamite. But here a distinction must be noted between two quite different kinds of prominences. The one kind, called eruptive prominences, are characterised by precisely that violence and rapidity of motion which we have in mind, and shoot upward from the surface of the sun sometimes with the peculiar gyrations of a whirlwind and with velocities of 100 or 200 miles per second, or even more. Prominences of this kind usually occur in connection with some great sun spot, or at least near to it, and the eruptive prominences in general seem limited to the same parts of the sun's surface within which sun spots occur, while the second kind, called quiescent prominences, occur indifferently at the equator or at the poles or at any intermediate part of the sun's surface. One of this kind is shown in the accompanying cut, where its size is compared with that of the earth. As their name indicates, these are much less violent in their movements than the eruptive prominences, and often float for hours, or even days at a time, above the chromosphere unchanged in appearance and as quiet as a summer cloud, which, indeed, they sometimes resemble in being entirely separated from the chromosphere, while at other times they rest upon and seem to form part of it. In general the eruptive prominences may be described as tall and comparatively slender, while the quiescent ones are lower and more wide-

spread. The spectroscope brings to light what is perhaps an even more significant difference between them, that the vapours of many metallic elements are found present in the eruptive prominences, while the quiescent prominences and the chromosphere seem for the most part composed of hydrogen and one other substance, called helium, which has been identified only recently as a terrestrial element of rare occurrence.

In referring to the spectroscope in this connection we must not neglect to say that by its use the prominences which are invisible in the ordinary telescope, except at the time of an eclipse of the sun, may be seen upon any clear day, as was found out almost simultaneously some sixty years ago by a French and an English astronomer, one of whom pointed his spectroscope upon a prominence during an eclipse and was surprised to find it remain visible long after the sunlight reappeared, while the other, from theoretical considerations, quite independently reached and published the conclusion that the spectroscope ought to make the prominence visible in full sunlight by enfeebling the background of ordinary light without correspondingly diminishing its own brilliance.

But we are not yet at the end of our list of invisible parts of the sun. Outside the chromosphere, enveloping the prominences and extending far beyond them, lies the largest part of the sun, a beautifully soft white crown of light surrounding it on every side and stretching away literally for millions of miles. This corona, as it is called, is absolutely invisible, save during the progress of an eclipse, and as these rare moments amount to only a few days per century, there need be little surprise that our

knowledge of the structure and peculiarities of the corona is scantier than of other parts of the sun. Some things, however, come out with tolerable certainty from the eclipse observations. The corona is, in part at least, a very rare gas or mixture of gases, one of whose components seems to be hydrogen, heated to a degree at which



TOTAL ECLIPSE OF THE SUN.
(Showing prominences, chromosphere, and corona.)

it is incandescent and, of course, hotter and denser in its lower portions, which, therefore, seem brighter than the outer parts. But the spectroscopic analysis of the coronal light seems to require us to believe also that intermingled with this gas, and forming a part of the complex structure of the corona, is a certain amount of solid matter, probably in the form of dust or fine liquid drops, which reflects to us the ordinary sunlight, and frequently gives to the corona the appearance of having a complicated and

beautiful structure, showing rifts and dark lanes extending outward from the sun, together with bright, curving filaments, sometimes curiously interlaced one with another and in a general way seeming to curve from the poles toward the equator of the sun. The shape of the corona and its extent vary in considerable measure from year to year. But at all seasons the substance of the corona must be astonishingly thin and rare, since in several cases comets in their motion about the sun have come so near to its surface as to cut their way through the corona, moving completely immersed in it for hundreds of thousands of miles without suffering any diminution of their velocity or the slightest apparent hindrance to their motion. But in spite of this tenuity the corona seems a fairly brilliant appendage of the sun, since its total amount of light probably falls little if any below that of the full moon, and it is only the overpowering brilliance of the central parts of the sun that masks its light under ordinary circumstances.

II. THE SUN.

By George Cary Comstock, Ph.B., LL.B.
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Third Paper.

In this concluding article, what we know of the constitution of the sun, as shown by the instruments of the astronomer, must be pieced together so far as possible into a mechanical explanation of the sun, just as the student traces out the combination of wheels and belts, levers and cams which make up the construction of any ordinary machine. But here the astronomer of the present time cannot hope to rival the mechanical engineer in the fulness of his knowledge, and it must remain a matter of grave doubt whether for centuries to come his understanding of the mutual relations of spots and faculæ and prominences, of corona and photosphere, can even approach a satisfactory completeness. For the present we must be satisfied with indicating some of the lines along which partial advances have been made toward such an understanding of the sun's mechanism, and marking as subjects for further research some of the points which require explanation beyond what can now be given.

Speaking broadly, the sun may be called a kind of heat

engine which runs backward—*i.e.*, instead of receiving heat from some external source and transforming that heat and giving it out as mechanical power, it is believed to transform mechanical work into other forms of energy, some small part of which comes to us as light and heat, but of which by far the larger part is scattered broadcast throughout the universe in what seems the most recklessly wasteful manner, for much less than one per cent. of its total output falls upon the earth or upon any other planet where it can be utilised in the ways with which we are familiar. In substance, this solar machine is a globe nearly 1,000,000 miles in diameter, intensely hot but set down in the celestial void, where it is free to squander its store of heat like the glowing filament of an incandescent lamp; more free, in fact, for about the sun there is no protecting screen of glass to check and diminish the wasteful radiation. Such a globe must be in process of cooling off, the outer parts more rapidly than the central ones, and we should expect to find as we pass from the regions below the photosphere to the outermost parts of the corona a progressive diminution of temperature, although even the outermost parts of the corona must still be white hot. Under these circumstances, a circulation will be set up in the fluid matter of the sun, currents by which the hotter central parts are brought to the surface and exchange places with the cooler matter upon the outside, and there can be little doubt that the circulation within the body of the sun stands in the closest relation to the phenomena which we see manifested at its surface.

Along with the rise of temperature which occurs from

the outer layers toward the central parts of the sun, there goes a great increase in the pressure to which the successive strata are subjected, since each lower layer has to bear the weight of all above it, and this produces a rather curious set of conditions at different levels within the sun. Owing to increase of pressure we expect to find, and do find, that the density of the gases which compose the corona and chromosphere increases as we go down to lower and lower levels, and the photosphere is certainly even more dense than they, since the continuous spectrum which it emits shows a more congested state of the molecules which compose it than is indicated by the discontinuous spectra of the gases above, and astronomers are agreed that in the photosphere the solar material is not in the gaseous state, but is in part, at least, liquid. Not, indeed, a continuous sheet of liquid like a layer of molten iron, but a vast multitude of independent drops clustered like those which make one of the clouds that float in our atmosphere, and the great brilliancy of the photosphere, many times surpassing that of the corona and chromosphere, is sufficiently explained by its liquid composition, since incandescent gases have far less power of giving off light than have liquids at the same temperature. This cloud layer, which we call the photosphere, is impervious to sight and furnishes the visible surface of the sun below which we cannot penetrate by direct search, but where it is almost, if not quite, certain that at still lower levels increasing temperature must again render the substance of the sun gaseous, for, after a certain limit of temperature is passed, no amount of pressure can keep the molecules in the liquid state. This internal gaseous condition we

shall find to be of the highest importance in connection with the continued maintenance of the sun's activities; but too much stress must not be laid upon the word gas, since, in their mechanical properties, the internal gases of the sun, on account of their great density, are surely quite unlike those of the earth, and they probably behave more like tar or soft mortar than like such a gas as air, but the constituent molecules are free to wander throughout the whole body of the sun instead of being limited to a very narrow range, as are those of the tar.

Returning now to the things visible upon the sun, it seems probable that an eruptive prominence is due to superheated matter which has been ejected from beneath the photosphere into the region of the chromosphere and the corona, where it cools and becomes a denser mass of mingled gas and smoke, and then falls back upon the photosphere, and for a time is visible as a spot obscuring and cutting off the light from the brighter surface of the sun, while detached portions of the original matter from below, checked in their upward movement, float in the surrounding atmosphere. That the spots are collections of cooler matter lying upon or near the photosphere, like slag upon molten iron, is agreed by all astronomers, but it must be confessed that when studied in detail they present many features not easily explained, and chief among these must be reckoned the ebb and flow in the process of spot formation, which renders them by turns numerous and few upon the face of the sun. Many attempts have been made to connect the sun-spot period of eleven years' duration from maximum to maximum of spottedness with external causes, such as the positions of the planets in

their orbits, the varying influx of meteoric matter into the sun, etc., but up to the present time these efforts have proved fruitless, and it now seems probable that the cause is an internal one unknown, but in its effects not unlike to that which produces the alternate activity and repose of a geyser. But, whatever its nature, this cause must be of profound significance in the mechanism of the sun and its effects may even be manifested here upon the earth in variations of the amount of solar energy which we receive from year to year. Serious attempts have been made from time to time to show that epidemics, storms, famines, the price of grain, etc., are in some way dependent upon the sun-spot period and tend to run in cycles of eleven years; but, while such effects cannot be called impossible, we shall do well to rank them for the present among things not yet proved. Another unexplained feature of the solar mechanism is that spots, eruptive prominences, and faculæ are confined to a certain limited part of the sun's surface on either side of the equator and do not appear near the poles, and equally unexplained is the connection between these phenomena and the extent and shape of the corona, which seems to change in size and outline in sympathetic dependence upon the sun-spot period.

It need not surprise us that the sun revolves about an axis somewhat after the fashion of the earth, since all of the other planets do the same thing, but it is certainly extraordinary that there should be different rates of rotation in different parts of the sun, the polar regions taking a considerably longer time for a complete revolution than do the equatorial parts. It would seem that such a con-

dition of things could not continue without some force being continually applied to overcome the friction of the parts as they flow past one another, but no such maintaining power has ever been discovered in the sun, nor does it seem probable that any such exists; and the most plausible suggestion yet made in explanation of this peculiarity of the sun is that we here witness the effect of some former disturbance or accident, such as a collision with another heavenly body, which has not yet had time to wear itself out, although tens of thousands of years may have elapsed since its occurrence.

To return to our conception of the sun as a machine, its output of radiant energy is clearly drawn from its own internal stores of heat, and the varied phenomena of its surface are connected with the transfer of that heat from below to above the photosphere. The sun must be cooling off and approaching that limit where, its stores of heat expended, it can no longer serve its planets as it now does. However great that supply of heat may be, it is ceaselessly drawn upon and ceaselessly diminishing, and if it were not constantly replenished, a very few thousand years must bring a sensible diminution in its amount and in our supply, cooling the earth and bringing the Arctic snows ever nearer the equator. That no such effect has been observed within the period of human history, twenty-five centuries or more, indicates some process within the sun by which its energies are maintained, and by virtue of which it is properly called a machine. As to the nature of this process, astronomers are almost unanimously agreed upon two processes, each of which doubtless contributes in some measure to maintain the

stores of solar heat. First, but least important of these, is the influx of meteoric matter, dust, and stones, which, coming from the outer regions, falls heavily upon the sun and warms it by its own impact, just as both cannon ball and target are warmed by the collision, when one is fired against the other. Let it be clearly understood that these meteors do not furnish fuel to the sun as coal is furnished to a furnace to be burned for the production of heat, since, as we have already seen, combustion is quite out of the question, the sun's temperature being far too high to permit of any such chemical process. It is their arrested energy of motion which furnishes the heat and furnishes it in far greater measure than could be had by burning them in any furnace.

But it is hard to believe that the available supply of meteoric matter is sufficient for the maintenance of the sun's heat, or for more than a very small part of it, and most astronomers look upon a progressive shrinkage of the sun's bulk as a more probable source for the greater part of its supplies of heat. Theory and experiment agree that if a gas is compressed, as by forcing down a piston in a cylinder, it will grow warmer, and the amount of heat thus produced stands in direct relation to the amount of work done in forcing the piston down. We have already seen that the great bulk of the sun is probably gaseous, and it is perfectly certain that the molecules of this gas are being constantly crowded together, compressed, by their mutual attraction, their gravity toward each other, which would squeeze them into an even more compact mass than they now are, were it not for the expansive force of the sun's heat. The gravity and the heat, in fact,

oppose each other, and between them regulate the size and density of the sun, since, if either force—the heat, for example—became for a moment predominant, it would expand the sun and pull its molecules apart until equilibrium was again established in the larger bulk. But, in the long run, the sun's heat is being lost, while the gravitative force, the weight of the molecules, suffers no corresponding loss, and therefore must produce a continuous shrinkage, which in its turn furnishes a fresh supply of heat, to be added to the sun's output.

A strangely simple mechanism for so great a machine, and a peculiarly efficient one, since computation shows that the amount of shrinkage required to maintain the sun's expenditure of light and heat is a matter of only a few miles per century—an amount so small as to be absolutely beyond the measuring power of our greatest telescopes. But, small as is the amount of this shrinkage, it is of the greatest import for the future career of the sun. It cannot continue forever, nor can the sun's bulk shrink to nothing at all, and unless the accepted belief of astronomers thus outlined is radically wrong, there must come a time at which the shrinkage will cease, the heat waste away, and the sun grow cold and still to his very centre. The machine now so active and so beneficent will have run down, and the astronomer of the present day knows no way in which it can be started again, rejuvenated, and permanently maintained in its present state of activity.

Our foundation of surely ascertained facts is too small to support very much theorising about the remote future of the sun, and the speculations of the preceding paragraph must be regarded as marking only a goal toward

which the present course of events is moving, and seems likely to continue moving. But, whatever that future course of events may be, so much at least is certain: The present condition of the sun is a transitory one, which may have lasted for many thousands of years, and probably will last for a very long time to come, but which is not eternal. The particular stage of development in which we see it had a beginning, and it will have an end, but what that beginning and ending are like cannot be certainly read from its present condition.

III. THE PLANETS.

By Charles L. Poor, Ph.D.

Sometime Professor of Astronomy, Johns Hopkins University.

First Paper.

As the stars appear night after night, year after year, they are found to maintain their same relative positions. Three thousand years ago the " Great Dipper " was hanging in the northern sky, just as it is hanging to-night; these stars seem bound together by some invisible tie. The wise men of old set them like jewels on the surface of the celestial sphere, at the centre of which was suspended the earth—an earth that was already known to be a globe.

Seven of the brightest celestial objects—the sun, the moon, Mercury, Venus, Mars, Jupiter, and Saturn—are soon seen not to be bound together like the other stars. These seven move around the earth more slowly than do the mass of their companions. If to-night the moon rise with the stars of Orion, to-morrow the constellation will rise nearly an hour before the moon appears. These seven wander through the heavens visiting the different constellations. Hence they are called " planets "—that is, wanderers.

Two of these planets—Mercury and Venus—never depart far from the sun; they appear to vibrate across that body, moving at equal distances on each side of it. They do not move uniformly, but when moving west they appear to go much faster than at other times. The other planets—Mars, Jupiter, and Saturn—have much more complicated motions. On the whole they move west ward until they complete a tour of the heavens, but this westward motion is very irregular. Sometimes they move fast, sometimes more slowly, even stopping at times and then moving eastward for a short period. Nor do they move in straight lines, but form curious loops and curves among the fixed stars.

MOTIONS OF MERCURY AND VENUS.

Fig. 1 illustrates the motions of the interior planets with respect to the sun. Mercury oscillates about the sun, going quite a distance from this body in an east and

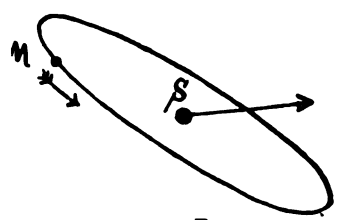


FIG. 1.

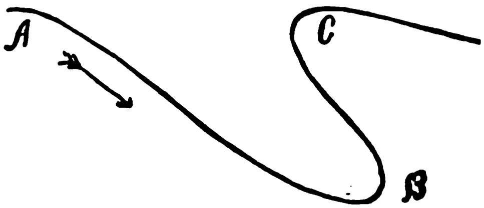


FIG. 2.

west direction, but never appearing far north or south. The sun appears to move forward in the direction of the large arrow, and Mercury is carried along with it; so that, besides its vibratory motion around the sun, Mercury is

carried by the sun around the circuit of the heavens. The apparent motion of Mercury among the stars is shown in Fig. 2, in which A B is its westward motion and B C is its eastward. These are both accomplished in about the same time, and as A B is much larger than B C, we see that Mercury appears to move much faster while going westward.

APPARENT MOTIONS OF AN EXTERIOR PLANET.

The motions of an exterior planet such as Mars are shown in the figures below. The planet will appear to move westward from A; as it nears B it begins to move more and more slowly, then stops, and finally moves east-

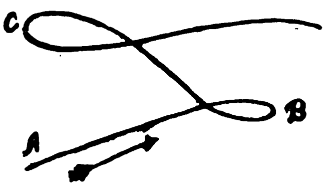


FIG. 3.

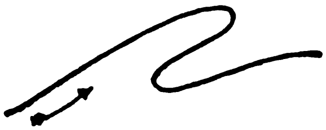


FIG. 4.

ward, not, however, returning on its path, but forming a node or loop. On reaching C the planet again changes the direction of its motions and begins anew on its westward course. A more simple form of curve is also shown. These motions, it must be remembered, are apparent—that is, the planet seems to move among the stars. Its real motion is something vastly different. The earth is itself in motion, and much of the motion which we attribute to the planets is really due to the motion of the earth. The above curves represent, therefore, the combined motion of the earth and planet.

At first the motions of these wanderers appear capricious, irregular; but a little careful study shows the planets to be moving in definite paths, which each one goes over and over year after year or century after century. The astronomers of old tried to map these motions, to form diagrams from which the places of the planets could be predicted at any time. They naturally, at first, thought the earth to be at rest and to be the centre of motion, and that the planets (including the sun) revolved about it. On this supposition Ptolemy, who lived at Alexandria about 150 A.D., built up a complete and satisfactory system of planetary motions. His tables were extremely accurate; he knew the shape of the earth and its approximate size; he could predict the time of rising and setting of the stars and planets. Of course, he had no telescope, and his observations were very rough as compared with those now made.

Copernicus showed that the sun, not the earth, is the centre of motion, and that the earth is a wanderer—a planet. Kepler, in 1610, followed with his wonderful laws of planetary motion, and thus made clear to the scientific world the true form of the "solar system" and the true motions and relative positions of the various members thereof. These first two laws are so important and so easily understood that I have reproduced them. They are as follows:

1. The orbit (or path in the heavens) of each planet is an ellipse, the sun being at one focus.

2. The line drawn from the sun to the planet passes over equal areas in equal intervals of time.

The first law gives the shape of the path each planet describes about the sun. These ellipses are of very small

eccentricity, and approach nearly to circles. So near circles are they, that on any scale drawing it would be impossible to detect the difference between an elliptic orbit and a circle drawn with the sun at the centre. Again, the law

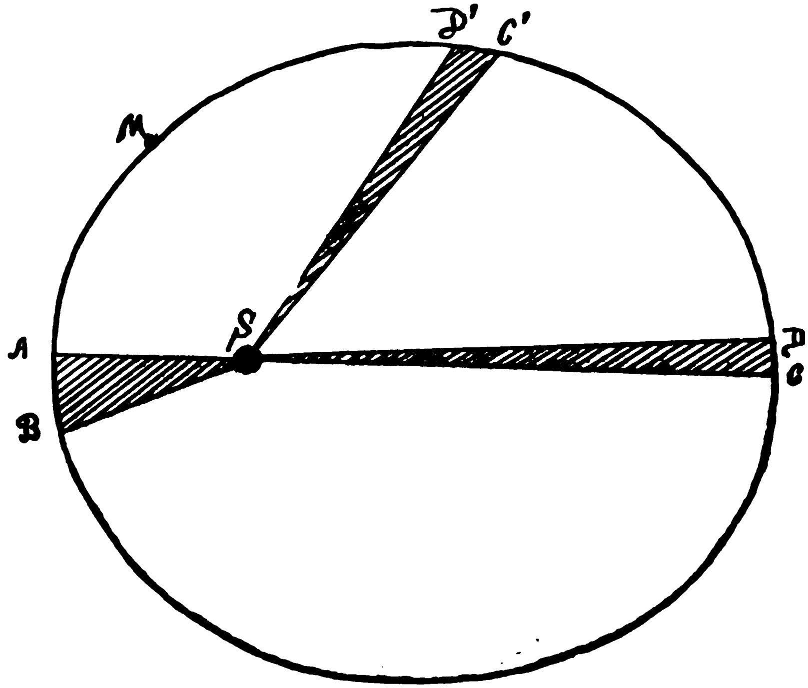


FIG. 5.

clearly shows that the sun is the chief body of the system and relegates the earth to its proper position among a group of planets—a small member of a large system.

The second law of Kepler deals with the speed with which the various planets travel about the sun. They

move sometimes faster, sometimes more slowly, and this second law gives the variation of speed. From it we see that each planet moves faster when it is in that part of its path which brings it closer to the sun.

The above figure (5) represents the orbit or path of a planet about the sun. The curve is an ellipse. The sun is supposed to be at S, one of the foci. The planet Mars, for example, travels around and around in the curve. The time in which the planet makes a complete revolution in its orbit is called its periodic time, and this varies from eighty-eight days for Mercury to about 165 years for Neptune. The planet moves around in its orbit with different speeds. If it takes the planet a week to move from A to B, then it will also take it one week to move from C to D, these latter two points being so situated that the areas of the vectors A S B and C S D are equal. In the diagram these areas are shaded. It is thus clearly seen that a planet must always move faster when nearer the sun. In the case of the earth, for example, it is nearer the sun in winter than in summer, and accordingly it moves faster in winter than in summer, passing over ninety degrees, or one quarter of its orbit, in two days' less time in winter than in summer.

This figure (5) does not represent the true form of the orbits of the planets, in that the difference between the greatest and least diameter of the curve is much exaggerated. Such a diagram drawn to a true scale would not differ appreciably from a circle. To properly represent the orbit of the earth, the distance A C in the above figure would have to be six inches, and then the sun, S, would be less than one-tenth (0.96) of an inch from the

centre. The unaided eye could not distinguish the curve from a circle. Thus, as we now know, the solar system consists of the sun as a central controlling, life-giving body, the planets revolving about the sun, and finally the satellites or moons that accompany the planets and revolve about them. As we pass outward from the central sun, the planets are Mercury, Venus, Earth, Mars, the group of several hundred small planets called planetoids, Jupiter, Saturn, Uranus, and Neptune.

An illustration will best convey to the reader a general impression of the relative magnitudes and distances of the planets. This illustration is taken from "Outlines of Astronomy," by Sir John Herschel: "Choose any well-levelled field; on it place a globe two feet in diameter; this will represent the sun; Mercury will be represented by a grain of mustard seed on the circumference of a circle 164 feet in diameter for its orbit; Venus, a pea on a circle of 284 feet in diameter; the earth, also a pea on a circle of 430 feet; Mars, a rather large pin's head on a circle of 654 feet; the asteroids, grains of sand in orbits of from 1,000 to 1,200 feet; Jupiter, a moderate-sized orange in a circle nearly half a mile across; Saturn, a small orange on a circle of four-fifths of a mile; Uranus, a full-sized cherry, or small plum, upon the circumference of a circle more than a mile and a half, and Neptune, a good-sized plum on a circle about two miles and a half in diameter. To imitate the motions of the planets in these orbits Mercury must describe its own diameter in forty-one seconds, Venus in four minutes fourteen seconds, the earth in seven minutes, Mars in four minutes forty-eight seconds, Jupiter in two hours fifty-six minutes, Saturn in

three hours thirteen minutes, Uranus in two hours sixteen minutes, Neptune in three hours thirty minutes."

The above illustration gives a good idea of the relative dimensions of the solar system; another will serve to show us the actual size of the great system. In astronomy the distance from the earth to the sun is the unit of measure, and in the above illustration this was supposed to be 215 feet, or half the diameter of the circle on which the earth travelled. The actual distance is about 93,000,000 miles—a distance so great that we can hardly form any definite idea of it. The fastest express train averages about fifty miles an hour and covers the distance from New York to Chicago in a little less than one day. Such a train, travelling at this rate day and night, without stopping for coal or water, would take over 200 years to cover the distance between the sun and the earth.

III. THE PLANETS.

By Charles L. Poor, Ph.D.

Professor of Astronomy, Johns Hopkins University.

Second Paper.

THE PHYSICAL CONDITION OF THE PLANETS.

The planets vary greatly in size and condition, but there are a few general characteristics that are common to all. In the last paper we saw that they all have similar motions about the sun; that, taken together, they form one large system of bodies—the solar system. In a most general way we may say that the earth is a sample of all the planets. Each and every planet is a solid or semi-solid globe of matter, non-luminous; shining, therefore, by light reflected from the sun. These balls all rotate on an axis in a manner similar to that of the earth, and therefore on each planet there is a recurrence of sunlight and darkness, or of day and night. Nearly, if not all, of the planets are surrounded by an atmosphere.

In discussing the condition of the planets, there are three features that are of special importance, and which render the planets so different among themselves. These are, first, the difference in their respective supplies of light

and heat; secondly, the difference in the nature and condition of the materials of which they consist; and, thirdly, the difference in the forces of gravitation on their surfaces.

In regard to the first of them, we know that the sun's light and heat are the source of all energy, of all life, if life there be, on the planets. The intensity of solar radiation is seven times as great on Mercury as on the earth, and on Neptune 900 times less. And on the other planets the intensity of the sun's radiation varies between these two limits. We must not infer from these figures that Mercury is much hotter than the earth and Neptune much colder. The atmosphere of a planet acts as a blanket and modifies the temperature to a great extent. The intense radiation of the sun easily passes through our atmosphere, while the less intense radiation of the surface of the earth is prevented from escaping. So that without a knowledge of the condition and density of the atmosphere of a planet we cannot safely conclude that it is hot or cold merely from its distance from the sun.

Second, in regard to the nature and condition of the materials that make up the planets, we know that in general the sun and all the planets are made up from similar materials. The elements which constitute the bulk of the earth are known to form the bulk of the sun, and are thought to form that of the planets. The spectroscope proves to us that iron, hydrogen, nickel, carbon, etc., which are so common on the earth, are also found in the sun. From many observations and considerations we are led to believe that the sun, the earth, and all the planets were formed from a single original mass of gas and that the same elements will be found to predominate

on all the planets. So much for the mere materials. They may, however, exist in the different planets under very different forms. On the earth carbon is found as coal and as diamonds. The planets show great diversity. Mercury is two and one-half times as dense as the earth, or over twelve times as dense as water. At the other extreme is Saturn, the density of which is only about one-half that of water. A piece of rock from Saturn would float on water and be as buoyant as cork, while a piece from Mercury would sink like lead.

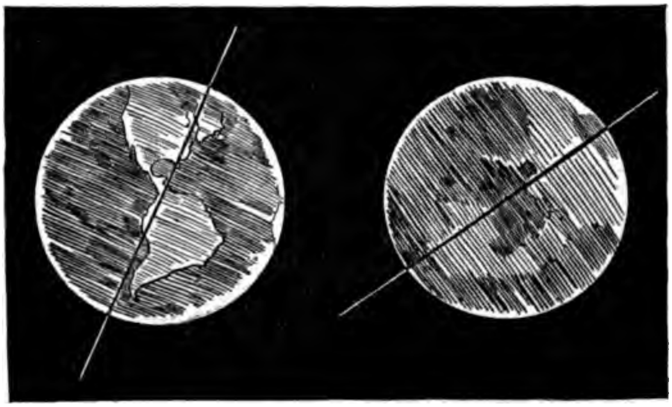
Again, as regards the third point, the strength of gravitation at the surface of the various planets. This depends upon the mass of the planet and its diameter. The greater the actual quantity of matter the planet contains, the greater the force of gravitation at its surface, while the force is diminished proportionally to the square of the radius of the body. On Mars the force of gravitation is the least, being only about four-tenths that of the earth, while on Jupiter it is the greatest, being fully two and one-half times that of the earth. That is, a man whose average weight is 150 pounds, would weigh only sixty pounds on Mars, while on Jupiter the same man would weigh 390 pounds. On Jupiter, again, owing to the rapid rotation of the planet, and to its ellipticity, the force of gravity varies greatly in passing from its equator to the poles, a body weighing one-fifth more at the poles than at the equator.

Passing from the more general considerations to a special view of each planet, we find that it is usual to divide them into two groups of four each. The first group, or terrestrial planets, as they are sometimes called,

include Mercury, Venus, the earth, and Mars. These are all bodies which do not differ greatly from the earth in size or in density. The second group contains the four large outer planets—*i.e.*, Jupiter, Saturn, Uranus, and Neptune. These are all much larger than the earth, and in general much less dense.

Mercury. Very little is really known about this planet. As it is always in the neighbourhood of the sun, never being more than thirty-eight degrees from that body, the study of its surface is exceedingly difficult. It must always be observed in twilight and near the horizon, both of which circumstances preclude accuracy. Seen in a telescope, it looks like a little moon, presenting phases precisely similar to those of our satellite. At times it appears full, like a small round disk of light; again it appears like the new moon—a thin crescent of silver light. Mercury is much smaller than the earth, much more dense, and it is supposed to have an atmosphere, though observations on this point are doubtful. Observations made during the last few years seem to point to the conclusion that it always presents the same face to the sun, in a manner similar to that in which the moon always shows the earth the same face. If this be so, there is no such thing as day and night on Mercury. On one portion of its surface the sun will always shine; on the opposite portion never. The variation in temperature would therefore be great. We may form some idea of the condition by imagining the sun always overhead in Florida. There would be eternal day, and the heat would be unbearable. Again, at the polar regions the sun would never shine, and the cold would be far more intense than

at present. On Mercury this difference of climate would be greatly exaggerated, for that planet receives seven times as much heat from the sun as we do. On one portion of its surface is perpetual day, perpetual tropical heat far more intense than on any portion of the earth; on the opposite portion perpetual night—a polar night of intense cold.



COMPARATIVE INCLINATION OF THE AXIS OF THE EARTH AND THAT OF VENUS.

Venus is our nearest neighbour. At her nearest approach to the earth she is but a trifle over 26,000,000 miles away, and no other body ever comes so near except the moon, and once in a while a comet. And yet we know almost nothing about the surface conditions there existing. This is due to the fact that she is covered with a dense atmosphere, probably a large percentage being clouds. The light from the sun is reflected from this cloudlike atmosphere and not from the surface of the

planet. Only occasional glimpses of its surface markings have been had. Some mountain peaks have probably been seen. It has been estimated that the depth of the planet's atmosphere is approximately fifty-five miles, that of the earth being reckoned as forty. The atmosphere is probably about twice as dense as our own. And, taking all the various methods of observation into account, it is extremely probable that the atmosphere of Venus is nearly the same in constitution as that of the earth, and that the dense clouds are water vapour.

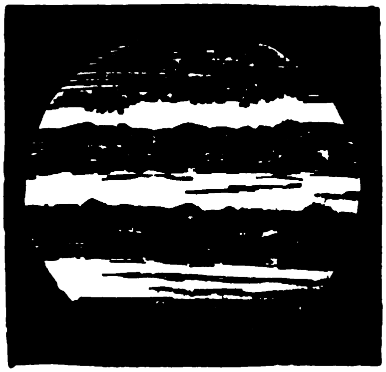
The other two terrestrial planets are the earth and Mars. Of the earth it is not my intention to speak. We all know the conditions that exist here. Of Mars I shall make a separate article. This for the reason that so much has been written about the planet and so many foolish notions exist and are encouraged by pseudo-scientists and popular writers.

Passing, therefore, to the group of outer planets, we note that two of them deserve special mention—*i.e.*, Jupiter and Saturn.

Jupiter is the giant of the solar system. His diameter is 86,000 miles, or nearly eleven times that of our earth. He rotates on his axis in the very short period of ten hours. This planet is, next to Saturn, the most beautiful object to study through a telescope. The markings of the disk are very prominent, and consist of a series of dark bands parallel to the equator of the planet. These are well shown in the accompanying figure. The markings are, however, *nearly all atmospheric;* they are cloud forms. Only occasional views are to be had of the real surface of the planet. This atmosphere is very dense, and probably

contains all the constituents of the earth's atmosphere, and the sun's light, by which we see the planet, is reflected from the upper portion of this dense atmosphere.

The characteristic modern discovery in regard to Jupiter is that it is a body midway in develpoment between the sun and the earth. Jupiter is still a hot body; not hot enough, indeed, to be self-luminous, but still hot enough



GENERAL ASPECT OF JUPITER.

to be semi-plastic. It is a large, cooling globe; semi-sun, semi-planet. Its surface temperature is probably far above that of boiling water, so that water can only exist in its vaporous form.

Some spectroscopic evidence has been taken which seems to show that Jupiter is self-luminous to a slight degree. Such observations from reliable observers are very few, and we are forced to conclude that native emissions of light from Jupiter are local and rare.

One of the very few surface markings of Jupiter was the great red spot. For several years this was the most con-

spicuous marking on the planet. It was first seen by Professor Pritchett in 1878. In size it was 30,000 miles long by 7,000 miles wide, its long side being parallel to the equator of the planet. At first its colour was a sort of pale pink, but after a few months it became a deep brick red. This spot remained a very brilliant object for about three years, then gradually faded. During the years of its greatest prominence it was carefully studied by many observers, but no satisfactory explanation of it was ever arrived at. Observations and investigations showed

THE PLANET SATURN.

what it was not, rather than what it was. It was almost certainly not self-luminous, and it was not permanently attached to any solid portion of the planet, for its period of rotation changed by more than five seconds in the ten years during which time it was observed.

Jupiter, together with his satellites, forms a miniature solar system. Of satellites he has five, four being discovered by Galileo in 1610, the fifth by Professor Barnard at the Lick Observatory in 1892. These all revolve about the planet exactly as our moon revolves about the earth. In size they compare favourably with the moon, the second having almost exactly the same diameter as our satellite, while three others are much larger. The third is the

largest, and is 3,600 miles in diameter—nearly one-half that of the earth. The fifth satellite is extremely small and very close to the surface of the planet. It is very difficult to observe, and can be seen only with the largest telescopes. The larger satellites are easily seen with the smallest telescopes, and they are exceedingly interesting bodies to watch. At nearly every revolution they pass

SATURN'S RINGS SEEN FROM THE FRONT.

into the shadow cast by Jupiter and are eclipsed. They also pass across the face of the planet, and at times their shadows show like small round dots on the planetary surface. The motions of these bodies are rapid, and nearly every evening some one or more of these interesting observations can be made.

Passing further outward from its surface, we come to the planet Saturn. Its distance is 886,000,000 miles, its diameter about 70,000, or more than nine times that of the earth. This planet shows cloud belts similar to Jupi-

ter, and as far as we know it differs but little in condition from Jupiter. Saturn is unique among planets. It is accompanied by eight satellites and is surrounded by a series of beautiful rings. These are well shown in the illustration. They were first seen by Galileo, but his telescope was so small that he could not distinguish their true character. Huyghens in 1665 first recognised them as true rings.

These rings—for there are three—are broad but extremely thin. The outer one is 168,000 miles in diameter, about 10,000 miles broad, and not more than 100 miles thick. They show irregularities, vary in thickness, and are not absolutely plane. For many years there was much discussion as to the nature of these rings. Some thought them to be solid matter, others liquid. Now it is known that they consist of a swarm of separate solid particles, each travelling about Saturn in its own independent path. They are in fact nothing more than a vast collection of little moons or meteors. This was conclusively proved by Clerk Maxwell, who showed mathematically that no continuous solid or liquid sheet could exist under the conditions that they are known to be in. This view has been confirmed by spectroscopic observations of Keeler, who showed that the different portions of the ring move with different velocities and with the velocities they should have if they consist of separate particles.

III. THE PLANETS.

By Charles L. Poor, Ph.D.

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Third Paper.

THE PLANET OF MARS.

The planet Mars has been the subject of observation and conjecture from prehistoric times. Its brilliant colour, its brightness, the extent of its motion among the stars, all tend to make it one of the most prominent of celestial objects. This planet has always been watched and studied with the utmost care and attention. In the early days of exact astronomy its motions among the stars were of the greatest interest to astronomers. From a long series of observations of this planet made by Tycho Brahe, Kepler deduced his celebrated laws of motion—the first grand step in our knowledge of the mechanical construction of the solar system.

Its mean distance from the sun is 141,500,000 miles; its sidereal period or year is twenty-two and a half months, or nearly two years. At its nearest approach to the earth it is about 35,500,000 miles distant, or 148 times as far

off as is the moon, and only about one-third as far as the sun.

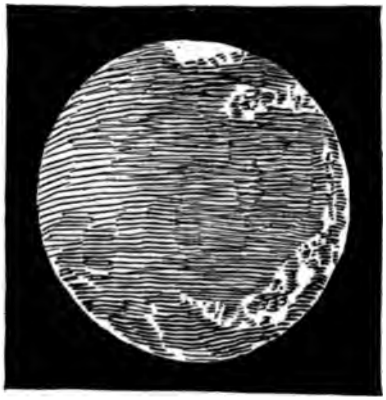
The real diameter of the planet is very closely 4,200 miles, a little more than half of the earth. The surface is about three-tenths that of the earth, or about the same as that of the dry land on the earth, omitting all oceans, etc. In other words, if we could cut the earth up, taking the continents alone, and form these into a new globe, we would have in size a fair representative of Mars.

Mars rotates on its axis in 24 hours 37 minutes and 22.6 seconds. Its day is, therefore, about thirty-seven minutes longer than our day. The inclination of its axis to the plane of the planet's orbit is nearly 24° 50′—not very different from that of the earth. The seasons on Mars are, therefore, very similar to those on the earth, excepting that each is nearly twice that of the earth—winter in Mars taking nearly six months, instead of three, as with us.

The mass of the planet, or the amount of matter it contains, is a little less than one-ninth that of the earth; the average density is seven-tenths that of the earth. On account of its small mass its attraction for bodies is much less than that of the earth; a body which weighs 100 pounds on the earth would have a weight of only thirty-three pounds on Mars.

Mars is accompanied by two satellites, which were discovered in August, 1877, by Professor Hall at Washington. These bodies are extremely minute, and both are close to the surface of the planet. Deimos, the outer one, is probably but five or six miles in diameter; Phobos, the inner one, is but little larger, being in the neighbourhood

of seven miles in diameter. This latter revolves about Mars in a period of seven hours thirty-nine minutes; its month is, therefore, less than one-third the day on Mars, and hence it rises every night in the west and sets in the east. Both satellites are often eclipsed—Phobos at every revolution. The physical condition of the planet has been carefully studied, and has given rise to much discus-

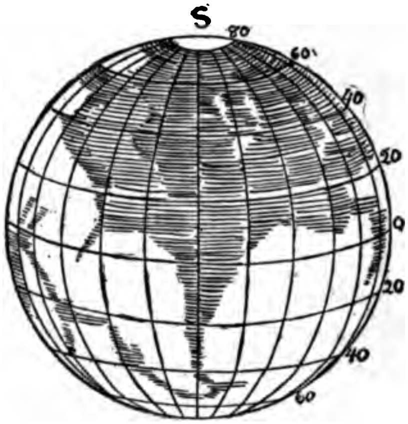


MARS THROUGH A TELESCOPE.

sion. By the physical condition I mean the character of its surface, of its atmosphere, the division of land, size of mountains, etc. Much has also been written about the possibility of life existing on this planet and the conditions under which it would have to be.

On examining the disk of Mars with a telescope of medium power (one of which the object glass is ten or twelve inches in diameter), it will be found to be of light yellowish colour, with a few irregular markings of grayish colour. The outlines of these markings are very in-

distinct, and the whole has a very hazy appearance. At one of the poles of the planet will probably be observed a very regular bright white disk—or polar cap, as it is called. These features are shown in the illustration. It shows the hazy character of the dark markings and the sharp, clear polar cap. These dark shadings are permanent features of the planet, and have been called seas and oceans—the lighter portions being called continents,



SEASONS IN MARS.

islands, etc. The southern pole is turned toward us, the cap being distinctly visible. This drawing is here reproduced as giving an absolutely fair reproduction of what is really seen with a telescope of fair power.

When the planet is watched with a large telescope, the tremours in our own atmosphere give the planet a wavy, indeterminate character. It is seen as stones are seen at the bottom of a stream of running water. Occasionally, however, the air will become steady for a moment, and

the markings will stand out clear and sharp, showing more details than are given in the illustrations. From such momentary glimpses the observer makes his pen or pencil sketch.

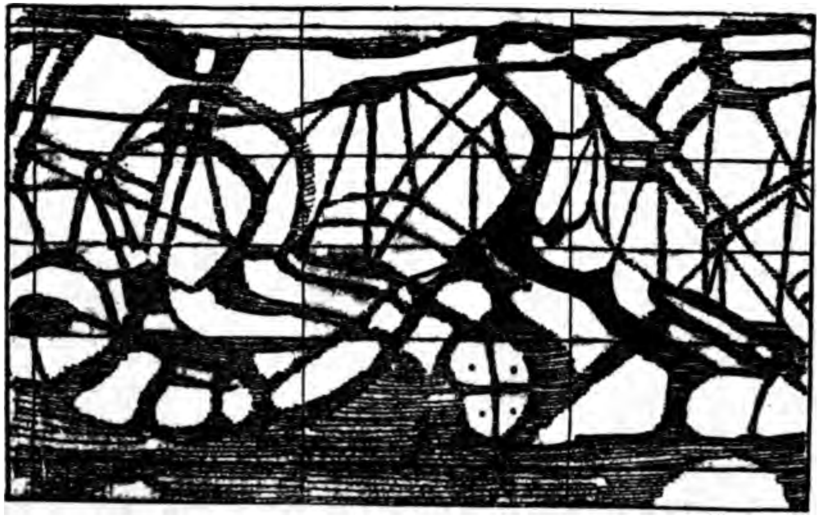
From these vague markings and brief glimpses we have to determine the entire condition of the planet. Before giving a statement of our present knowledge, it will be wise to pass in brief review the work of earlier observers; this will lead to a better appreciation of what is now being done, and to a better understanding of the views now held by conservative scientists.

Mars was one of the first objects to be studied with the telescope. As early as 1638 we find Fontana making drawings and recording his observations of spots and markings upon the ruddy disk of the planet. Unfortunately, however, nearly all Fontana's markings can now be shown to have been optical illusions, due to defects in his puny telescope. In 1666 Cassini determined the period of rotation of the planet, the length of its day, and found it to be very nearly equal to our own. His drawings show some of the permanent surface markings. Nothing further was discovered until 100 years later, or in 1780, when the great telescopes constructed by Sir William Herschel were first used. He found the polar caps to be true ice caps, similar in all respects to those which surround the poles of our earth. This explanation implied the existence of an atmosphere surrounding and enveloping the planet—an atmosphere in which the vapour of water was carried from the warm regions of the equator and deposited in the form of snow at the poles. Besides these caps there were recognised in the planet dark mark-

ings, some of which were of a permanent character and some variable; the former were ascribed to actual differences on the surface, as between land and water; the latter to clouds in the atmosphere.

During the major part of the present century, and to within the last few years, but little new was added to our knowledge of the surface condition of Mars. The markings on the disk were more accurately mapped. The darker portions were ascribed to the presence of large masses of liquid or water; the lighter portions were designated as continents, islands, etc. The orthodox view a few years ago regarding Mars was, then, as follows: A miniature earth, having about one-third the surface area of our planet; its surface divided into land and water; its polar seas covered with ice in the winter; its atmosphere similar to our own. Here, however, the analogy with the earth ends. The distribution of land and water was thought to be utterly different from that upon our planet. On Mars land predominates, the southern hemisphere being nearly all land. Near the south pole we have the great southern ocean, which contains very many islands. For the rest the surface is cut by narrow bays and long, deep seas. Such was the state of our knowledge in regard to this planet twelve or fifteen years ago.

About this time Schiaparelli, from his observatory at Milan, announced that all the continents of Mars are furrowed by a fine network of dark lines, some not more than 300 miles long, others many thousands, stretching clear across the entire hemisphere. Some of these lines were nearly 180 miles wide, others less than twenty. These are the celebrated canals. For some years Schiap-



THE SO-CALLED CANALS OF MARS.

arelli's discovery was received with great doubt by many, but the canals (for so I shall call them) have long been seen by so many different observers that their existence is an established fact in Martian geography. Though their existence is established and admitted by all, yet, as we shall see, their real significance, their true nature, is as yet unknown. These canals are permanent features of the planet; their length and arrangement are constant; their visibility changes capriciously. Every canal begins and ends in a dark spot or in another canal. Their normal appearance is that of uniform dark strips, but the colour is identical with the so-called seas. They are generally of a uniform width throughout their length, though a few expand and become funnel-shaped when they enter the darker portions.

The term canal, as applied to these appearances, is not fortunate, for it has led to much unscientific discussion and to speculations as to their construction by hypothetical inhabitants of the planet. Some French and American writers of considerable prominence among certain classes of readers have done much harm by spreading broadcast in a most attractive form hypothesis upon hypothesis, conjecture added to conjecture—and all as though they were established scientific facts. It is the height of absurdity to speculate about the inhabitants of Mars, when, as we shall see, we know absolutely nothing definite as regards the conditions of the planet itself.

The dark strips, however, have been thought to be true canals in one sense, and in that sense only—that is, they seem to be intimately connected with the distribution of Martian liquids. I have already mentioned the caps that

surround each pole. The observations in '82, '84, and '86 all point conclusively to the fact that these caps are sheets of ice or, rather, of a substance that solidifies with cold and melts with heat. As the Martian summer advances, these caps are gradually seen to turn dark and to melt, and the liquid diffuses itself gradually over the rest of the planet, and it is this diffusion of liquid that the canals aid. As the caps melt, large temporary seas are formed, and the canals grow wider and darker and increase in number.

THE SOUTH POLE OF MARS.

The explanation of the canals as true distributers of liquids is not without serious objections, for observations have shown that they cut through hill and valley—that over great distances the liquid must flow at different times in opposite directions. It has been well said that if they be true canals the engineering feat surpasses the tales of Baron Munchausen. Think of connecting Rio Janeiro, San Francisco, and New York with a system of straight canals, passing directly over mountains and oceans, seas and lakes; and, further, that in summer the water is to flow from New York to Rio, in winter from Rio to New York! The bed of the canal to slope different ways at different seasons!

Again, observations made in 1888, 1890, and 1892, at the Lick Observatory, and confirmed at other places, show the presence of mountain ranges on the planet. And one striking feature of the observations is that these mountains are both on the light and the dark portions of the planet, on the land and on the so-called oceans. The carefully mapped and named seas and oceans are found to be rough, irregular, even mountainous, land. History repeats itself. The dark markings in the moon, familiar to every child as the "man in the moon," were first thought to be large seas and oceans, and they still bear the names of oceans; but good telescopes soon showed these illusive seas to be mountainous lands, similar in all respects to the rest of the moon. We now know that no water exists on the moon; that the markings are merely different coloured portions of the same rough surface. We have the same effects upon the earth; the soil of New Jersey is deep red; the sands of the neighbouring beaches are white. So on Mars the dark markings are different coloured soil—mountains and plains formed of different coloured rock from that which forms the lighter portion of the planet. Observers are now nearly unanimous in the conclusion that there is little or no water on the surface of this interesting planet.

The spectroscope confirms this, or, rather, this powerful instrument of research fails conclusively to show the presence of water on Mars. All it can show, however, is that water is not there in great quantity; that it is not abundant in the atmosphere. Some of the most noted spectroscopists claim to have undoubted evidence of water on Mars.

During a period of several years an opinion has prob-

ably been gaining among the scientists that there is no water or water vapour on Mars. According to this view the polar caps are formed of solidified carbon dioxide gas, and this gas forms the chief constituent of this Martian atmosphere. This harmonises the various observations, and is supported by the kinetic theory of gases. Investigations show that Mars is unable to retain in its atmosphere gases and vapours such as form the constituents of the earth's atmosphere. If Mars were to be furnished with a new, abundant supply of water vapour in its atmosphere, it would soon lose it all.

Our conclusion may well be that a little knowledge is dangerous, that too wide and sweeping conclusions have hitherto been drawn. In fact, we know very little in regard to the conditions existing on Mars. We have, to be sure, a great mass of observations and many beautiful drawings, but in the interpretation of the phenomena we are still far from arriving at satisfactory results. All that we can definitely say as to the conditions existing on Mars may be briefly summed up:

1. The planet is surrounded by a very light atmosphere. Such an atmosphere cannot be one-fourth as extensive as our own. The presence of water vapour is not conclusively proved.

2. The surface of the planet is irregular and shows the presence of matter in two distinct forms, hitherto called land and water. Both are now known to be solid, different-coloured earths, as it were. In what way the lighter portions of the planet differ from the darker portions is not definitely known.

3. The atmosphere and vapours are condensed by cold,

and deposited as caps at the poles. These melt and disappear during the Martian summer.

4. The conditions on the surface are not such as would support life or vegetation such as we know on earth. No form of life known to us could exist on the planet Mars.

5. All talk of Martian inhabitants is the height of absurdity. It is absolutely unscientific, and cannot be supported by any reason whatsoever.

IV. THE MOON.

By Walter Charles Lockyer, B.A.

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First Paper.

The moon is our nearest celestial neighbour. Its distance is but thirty times the diameter of our globe. This insignificant distance, about 238,000 miles, is scarcely worth considering in astronomical measurements. Travellers by ship and rail, and even on foot, have passed over a distance greater than that which separates us from the moon. A telegraphic message would be delivered in a few seconds. It is but the four hundredth part of the distance which separates us from the sun, and only one hundred-millionth part of the distance which separates us from the nearest fixed star. If the distance to the moon were only one step, it would take 100,000,000 steps to reach the region of fixed stars. The distance to the moon is determined by astronomers with a precision greater than that with which we measure ordinarily terrestrial distances, such as the length of a road or of a railway. A cannon ball fired at a constant velocity of 1,640 feet a second, if this were possible, would take eight days, five

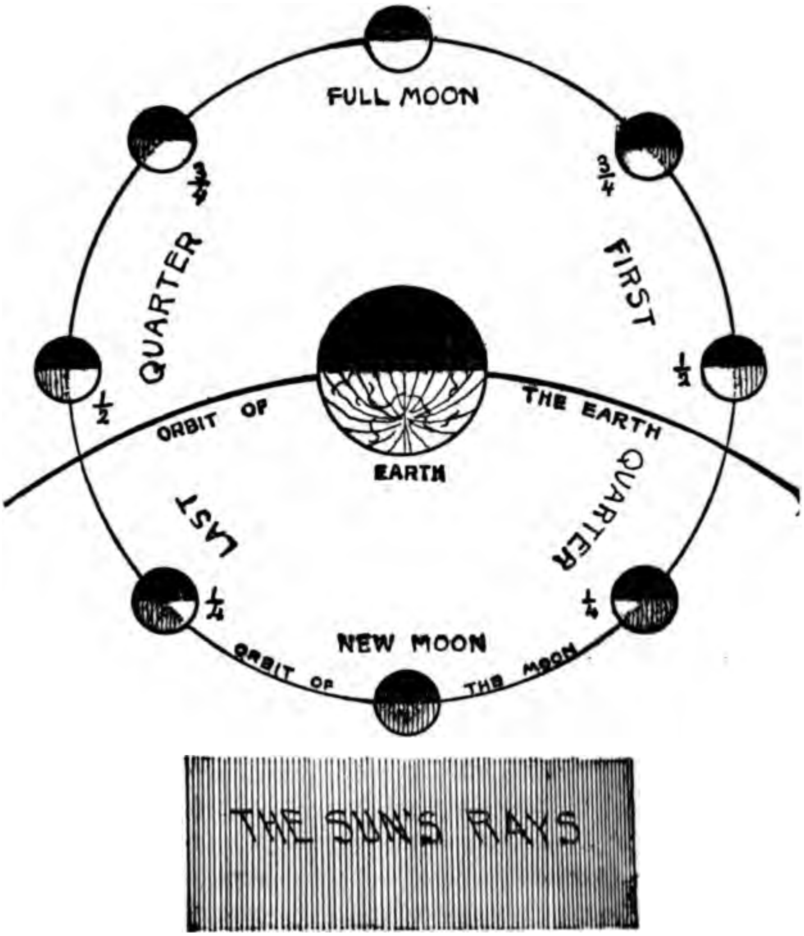
hours to reach the moon. But light, which has the most rapid of all known motions, darts from the moon to the earth in a second and a quarter.

The moon, when fully illuminated, seems to be a perfect circle; that is to say, the measured diameters in all directions are the same. We know that the earth and other planets are spheroidal, or more or less flattened at the

APPEARANCE OF THE MOON THROUGH A SMALL TELESCOPE.

poles, and we know also that this flattening is due to axial rotation, the extent of the flattening depending upon the speed of rotation. But the axial rotation of the moon is so slow that the flattening produced thereby is so slight as to be imperceptible to our observation. It is sufficient for the purpose of these lectures to assume that the moon is a sphere, the diameter of which is 2,160 miles.

The moon turns round the earth in a revolution of which the duration is twenty-seven days, seven hours, forty-three minutes, with a velocity of about two-thirds



Phases of the Moon.

of a mile a second, or thirty-seven miles a minute, and which produces a centrifugal force tending every instant to increase the moon's distance by a quantity exactly equal to that which the attraction of our globe tends to make it approach, so that it finally remains suspended in space, always at the same mean distance. The orbit which it describes round us measures nearly 1,500,000 miles.

It is important that we should know the mass or weight of the moon, because the weight of a body taken in connection with its size furnishes us with a knowledge of its density, or the specific gravity of the material of which it is composed. To solve this problem, we must appeal to Newton's law of universal gravitation. This law teaches us that every particle of matter in the universe attracts every other particle with a force which is directly proportional to the mass and inversely proportional to the square of the distance of the attracting particles. There are several methods by which this law is applied to the measurement of the mass of the moon. One of the simplest is by the agency of the tides. We know that the moon attracts the waters, producing a certain amount of elevation, and we know that the sun produces a like elevation, but to a much smaller extent, owing to its much greater distance. By accurate measurement of the solar and lunar tides, and due allowance being made for the difference of distance of the sun and moon from the earth, we can compare directly the effect that is due to the sun with the effect that is due to the moon; and since the masses of the two bodies are just in proportion to the effects they produce, and knowing the sun's mass, it is a simple problem in mathematics to find the mass of

AN IDEAL SKETCH OF PICO, AN ISOLATED MOUNTAIN IN THE MOON.
(As it would probably appear to a spectator on the moon's surface.)

TWO LUNAR VOLCANOES: ARISTARCHUS AND HERODOTUS
From photographs by Rau.

the moon. There are other methods, however, known to astronomers, and these prove beyond a doubt that the weight of the earth is eighty-one times the weight of the moon. The cubical contents of a body compared with its weight gives us its density. The earth's mean density is about five and five-tenths times that

COMPARATIVE SIZES OF EARTH AND MOON.

of water; that is to say, the earth weighs five and five-tenths times heavier than it would weigh if it were entirely water. We find that the moon's mean density is three and four-tenths times that of water, showing that the material of the moon is lighter, bulk for bulk, than the material of the earth. This specific gravity of the

material of the moon (three and four-tenths) is about the same as that of flint glass, and nearly coincides with that of some of the aërolites that have from time to time fallen to the earth.

We must bear in mind that the mass or weight of a planetary body determines the weight of all objects on its surface. What we call a pound on the earth would not be a pound on the moon. When we say that a particular object weighs ten pounds, we really mean that the attraction of gravity is ten pounds, and that it takes ten pounds of muscular force pulling the other way to counteract the force of gravity. As a matter of fact, an object which would weigh six pounds on the surface of the earth would weigh only one pound on the surface of the moon; and it follows as a consequence that any force, such as muscular exertion, or the energy of explosive forces, would be six times more effective upon the moon than upon the earth. A man who could jump six feet from the earth could, with the same muscular effort, jump thirty-six feet from the moon. The earth revolves on its axis about thirty times more swiftly than does the moon; for, while our day is twenty-four hours long, the lunar day is equal to twenty-nine and one-half of our days; that is, the moon turns around once on her axis while going once around the earth. While the moon revolves around the earth the earth itself revolves around the sun, and for this reason it requires about twenty-nine and one-half days for the moon to come into the same position with respect to the sun and the earth.

The moon is a dark globe, like the earth, which has no light of its own, and is only visible in space because it is

From "Flame, Electricity and the Camera," by George Iles.

A COMET, PHOTOGRAPHED BY DR. DAVID GILL IN 1882.

(With incidental portraiture of stars invisible in the telescope.)

illuminated by the sun. When the moon is between us and the sun its illuminated hemisphere is naturally turned toward the sun and we do not see it; this is the epoch of new moon. When it forms a right angle with the sun, we see half the illuminated hemisphere; this is the epoch

LUNAR CRESCENT.

of quarter. When it passes behind us, relatively to the sun, it shows the whole of its illuminated hemisphere; this is the full moon. The dark portion of the moon is dimly visible, owing to the reflected light of the earth; that is to say, in the dark portion there is moonlight, but the moon in this instance is the earth. The light which the "full"

earth sends to the moon is fourteen times that which the full moon sends to the earth. This lunar light generally presents a greenish-blue tint, indicating that our planet, seen from a distance, would show this shade. The student will note that the convexity or back of the slender crescent of a new moon is always turned toward the sun.

Any phase of the moon returns after an interval of twenty-nine and one-half days. Now it is found that nineteen solar years, or 6,940 days, contain almost exactly 235 lunations. Hence, after nineteen years, the same phases of the moon return on the same days of the year, on the same dates, so that it is sufficient to have registered these dates during nineteen years in order to know them in advance during all the following periods of the same length. That is to say, if we have full moon at 9 P.M., Monday, June 20, we shall not have full moon again at that hour, day, and date for nineteen years. This cycle is in fault only one day in 312 years.

This rule serves to determine in advance the dates of the Church festivals after the date of Easter. The first Sunday which follows the full moon of the equinox is fixed as Easter. It is assumed that the vernal equinox always occurs March 21, so that Easter is fixed as the first Sunday which follows the full moon after March 21. It follows from this that Easter cannot occur earlier than March 22, nor later than April 25.

The orbit of the moon is not situated in the plane in which the earth moves around the sun. If the moon revolved around the earth in the same plane in which the earth revolves around the sun there would be an eclipse of the sun at every new moon and an eclipse of the moon

at every full moon. The plane in which the moon moves is inclined five degrees to ours.

Five-sixths of the sunlight which falls upon the moon is absorbed, the rest being reflected away. The sun gives 600,000 times as much light as the full moon. It is said that if the full moon could shine upon us steadily for a year it would give us as much heat as the sun gives us in three minutes.

IV. THE MOON.

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Second Paper.

Whether the moon has an atmosphere or not is the subject of a good deal of controversy. We are all familiar with the phenomena of the terrestrial atmosphere; with the effects that are attributable to it. There certainly is no evidence of clouds on the moon, though it is stated that this may be due to the non-existence of moisture. It may be that water is present in the form of ice; this it is impossible to determine. When the moon is observed with high telescopic powers, all its details come out sharp and clear, without the slightest change or evidence of cloudiness. The non-existence of clouds, however, is not a conclusive proof of the non-existence of an atmosphere, for the atmosphere which produces clouds contains the elements of water. A lunar atmosphere should be detected in a solar eclipse. All gases and vapours absorb some portion of any light which may shine through them. If, then, the moon has an atmosphere, its black nucleus when seen projected against the bright sun in an eclipse

would be surrounded by a zone of shadow, as shown in the accompanying illustration. No such shadow has at any time been observed. Again, if an atmosphere existed, stars in passing behind the moon would suffer some diminution of brightness as they approached the apparent contact with the moon's edge. It has been observed in this connection that stars of the smallest magnitude visible

under such circumstances retain their lustre unimpaired up to the moment of their disappearance behind the moon.

Again, if there were an atmosphere about the moon not sufficiently dense to form a hazy outline, it would manifest its existence in another way. As the moon advances upon the sun's disk, the latter assumes, of course, a crescent form. If air or vapour enveloped the moon, the exceedingly delicate cusps of this crescent would be distorted or turned out of shape. At no observation has anything of this kind been noticed.

The twilight of the earth is due to the reflection of light by the atmosphere envelope when the sun is below the horizon. If, then, an atmosphere enveloped the moon,

there should be a region of twilight between the brilliantly lighted part and that in darkness; but no twilight is evident.

There are many other proofs put forth by astronomers of the non-existence of air on the moon, and if there be no air, we are almost forced to conclude that there can be no water; for, if water covered any part of the lunar globe, it must be vapourised under the influence of the long period of uninterrupted sunshine (nearly 300 hours) that constitutes the lunar day, and would manifest itself in the form of clouds or mists obscuring certain parts of the surface. But no such clouds or mists are ever visible.

Those parts of the moon which the ancient astronomers assumed from their comparatively smooth and dusky appearance to be seas, have long since been discovered to be merely extensive regions of less reflective surface material. It must be remembered that the moon has fourteen days of continuous direct sunlight, which, under the conditions existing upon the earth, would make intense heat; and this long day is followed by fourteen days of continuous darkness, or, rather, of moonlight (with the earth for a moon), which, under terrestrial conditions, would mean intense cold. The student must remember, also, in his study of this subject, that the density of the air on any planet depends on the attraction of the planet. If the terrestrial gravity were reduced to that of the moon, the atmospheric pressure and the density of the air would be reduced to one-sixth of their present state; a given quantity of air, at the level of the sea, would occupy more space, and the whole atmosphere would expand in a corresponding proportion; it would rise six times higher. If, then,

the moon had an atmosphere constituted like ours, this atmosphere would be six times higher than ours and the pressure would be equal to a sixth of that of ours. However, the bulk of the evidence goes to prove that neither air nor water exists upon the moon. Flammarion admits that there may (and there should) exist on the moon an atmosphere of feeble density and, probably, of a composition very different from ours.

Our conception of space should embrace time and space. In space we see across millions and millions of miles; in time we may travel back through millions of centuries. Our position and our time are important to us, but they are absolutely nothing in nature. That a world is inhabited to-day, or that it has been yesterday, or that it may be to-morrow, is the same thing in eternity. The moon is a world of yesterday; the earth is the world of to-day; Jupiter is the world of to-morrow. The idea of time is thus fixed upon our minds like that of space. It may be that there was a time when the moon was as full of life as is our earth to-day. The earth may have been the centre from which the moon gathered such life-giving properties as we gather from the sun in this our cycle of existence.

The lowest forms of vitality cannot exist without air, moisture, and a moderate range of temperature. It may be true, as recent experiments seem to show, that organic germs will retain their vitality without either of the first, and with exposure to intense cold, and to a considerable degree of heat; and it is conceivable that the mere germs of life may be present upon the moon. However, it is inconceivable that any plant life such as we are familiar

with could survive exposure, first to a degree of cold vastly surpassing that of our arctic regions, and then in a short time (fourteen days) to a degree of heat capable of melting the more fusible metals.

Since there is no atmosphere on the moon, there can be no sky light, for there is nothing above the lunar world to diffuse the solar beams; not a trace of that moisture which scatters some of the sun's light and which gives a certain degree of opacity or blueness to the heavens by day. The moon's sky must be as dark as that with which we are familiar upon the finest moonless nights, and this blackness prevails in the full blaze of the lunar noonday sun. If the eye (upon the moon) could bear to gaze upon the sun it would see the nebulous and other appendages which we know as the corona, the zodiacal light, and the red solar protuberances; or if these appendages could not be viewed with the sun above the horizon, they would certainly be seen in glorious perfection when the sun was about to rise or immediately after it had set. And, notwithstanding the sun's presence, the planets and stars would be seen to shine more brilliantly than we see them on the clearest nights. The stars would never twinkle, for this is caused by our atmosphere, and they would retain their full brightness down even to the horizon.

To nearly one-half of the moon (the hemisphere which we never see) the earth is never visible. The earth would appear from nearly all parts of the other lunar hemisphere to describe a small circle in the sky. In some regions only a portion of the terrestrial disk would make its brief appearance. A spectator on the moon would see the earth as a glorious moon. The diameter would be four

times as great as that of the moon itself, as seen by us, and the area of its full disk thirteen times as great. The greatest beauty would be seen during the lunar night, for at lunar midnight this globe of ours is fully illuminated. The lunar spectator would behold the sublime spectacle

TYPICAL LUNAR LANDSCAPE.
(The earth as a moon.)

of a total solar eclipse, and that under circumstances which render the phenomenon far more imposing than its counterpart can appear from the earth. To a spectator on the moon the earth would appear to have a diameter four times that of the sun, and, as a consequence, the total-

ity of the eclipse (the sun passing behind the earth) would continue several hours. As the sun passed behind the earth, the latter would be encircled upon the ingoing side with a beautiful line of golden light, deepening in places to glowing crimson, due to the absorption of all but the red and orange rays of the sun's light by the vapours of our atmosphere. As the eclipse proceeded, this ruddy glow would extend itself nearly if not all around the black earth, and so bright would it be that the whole lunar landscape covered by the earth's shadow would be illuminated with faint crimson light. We see this reddening during an eclipse of the moon. From the moon the whole effect would be to make the grand earth-ball hanging in the lunar sky like a dark sphere in a circle of glittering gold and rubies.

Because of an optical illusion, the moon seems larger near the horizon. The distance seems greater on account of the intervening objects, or because of the haze, fog, or smoke near the horizon. This illusion may be dispelled by the following simple experiment: Roll a thin sheet of paper, making a tube about twelve inches long and as large as a lead pencil. With one eye look through this tube at the much-enlarged sun or moon near the horizon, and you will notice that the disk will not seem greater than its natural size. The eye behind the tube is not deceived, because it sees only a narrow ring of sky around the moon, the tube cutting off intervening matter.

The question of the moon's supposed influence upon the weather and upon seedtime and harvest is an interesting one to the popular mind. The most careful scientific observations, dating back for many years, go to disprove

any connection between the moon and the weather, and class the whole category of signs and times as the merest superstition. This may, however, be only one more illustration of the familiar statement that you can prove anything you please by statistics. It is very clear that there is absolutely no foundation whatever for the widespread notion that weather changes may be expected with the moon's "changes."

IV. THE MOON.

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Third Paper.

With an ordinary opera-glass the observer can satisfy himself that the surface of the moon presents pronounced inequalities. The variations of light and shade induced the belief long before the invention of the telescope that seas and continents alternated upon the moon's surface. Untutored gazers detected in the light and shade the indications of a human countenance, and it may be that the earliest map of the moon was a rough reproduction of a man's face. Others recognised in these spots and shades the configuration of a human form, head, arms, and legs complete, which a French superstition that lingers to the present day held to be the image of Judas Iscariot, transported to the moon as a punishment for his treason. Some ancient writers supposed the moon to be a sort of mirror, which reflected upon its surface the image of the earth. Humboldt affirmed that this opinion had been preserved to his day as a popular belief among the people of Asia Minor. The moon was one of the earliest objects, if not actually the first, upon which Galileo turned his telescope,

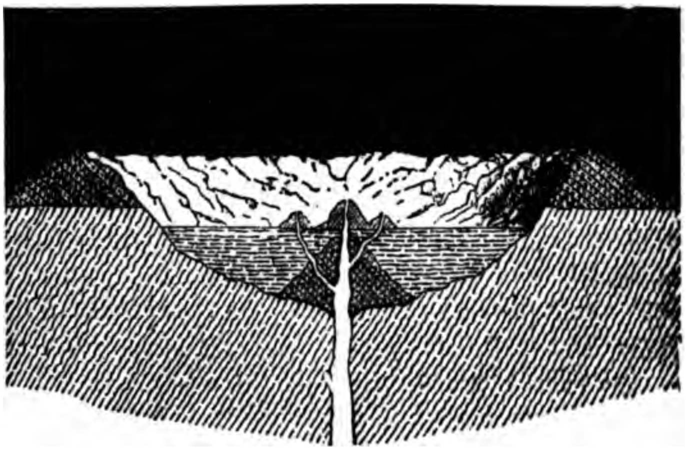
Typical Lunar Mountain.

and it was he who discovered that the roughness and inequalities of the surface were due largely to mountains and craters and the shadows which they cast. Modern telescopes bring the moon from a distance approaching a quarter of a million miles to a distance of perhaps a hundred and fifty miles, and modern observers have satisfied themselves that the surface of the moon—at least the hemisphere turned toward the earth—presents hundreds, perhaps thousands, of craters, some large and others quite small, scattered over a withered, parched, and apparently dried-up surface

Take an opera-glass, or a small telescope, and observe the moon when next it is full. In the lower part, and slightly to the left, will be seen a very brilliant white spot, from which curved lines seem to radiate. This is the famous mountain Tycho. It is one of the most colossal and majestic of all the moon's mountain formations. The crater of Tycho is about fifty miles in diameter, and this mountain appears to have been the centre of the most intense volcanic action. A little north and east of the centre of the lunar disk will be seen the greater crater, Copernicus. The walls of this crater are over fifty miles in diameter and 13,000 feet high. The immensity of these lunar craters will be appreciated when we remember that the largest active volcano upon the earth does not present a crater more than a thousand yards in diameter. It is supposed that the bright streaks are a record of what were originally cracks (as in a broken window) in the solid crust of the moon, resulting from some tremendously powerful upheaving agency. The cracking of the crust must have been followed by the ejection of subjacent molten matter

up through the openings; this spreading on either side has left the bright streaks, which are clearly visible.

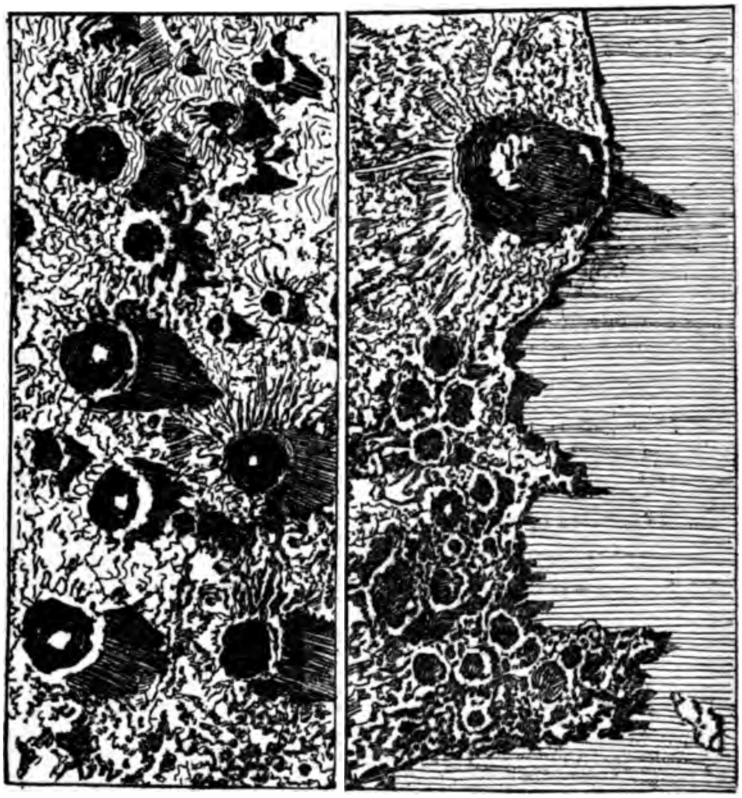
It is at the boundary of sunlight on the lunar globe that we see these craterform spots to the best advantage, as it is there that the rising or setting sun casts long shadows over the lunar landscape and brings elevations and asperities into bold relief. They vary greatly in size,



SECTIONAL VIEW OF LUNAR CRATER.

the smallest being so minute as to need the most powerful telescopes and favourable atmospheric conditions to see them at all.

Another striking feature of the lunar surface is the areas of seemingly smooth plains that have the appearance of dusky spots and that collectively cover about two-thirds of the entire disk. It was supposed by early observers that these shaded portions were seas. It is possible that



A VOLCANIC DISTRICT—THE MOON. RELIEF MAP OF A VOLCANIC DISTRICT NEAR NAPLES.

(Topography of lunar and terrestrial volcanic districts compared.)

these dark plains bear the same relation to the more brilliantly illuminated portions that our prairie country does to the Rocky Mountain district.

We thus see that the classes of features observable upon the moon may be summed up as craters and their central cones, mountain chains with occasional isolated peaks, smooth plains, with more or less irregularity of surface and bright radiating streaks. In some parts there is a great diversity of colour, the cause of which has not been explained. The student must remember that even with the most powerful telescope a lunar object 200 yards in diameter would appear as a point so small that we could not tell whether it was round or square.

The term crater has been used to represent nearly all the circular hollows that we observe upon the moon; and without doubt the word in its literal sense, as indicating a cup or circular cavity, is aptly applied. We have upon the earth some few instances in which the geological conditions which have determined the surface formation have been identical with those upon the moon, and as a result we have some terrestrial volcanic districts which, could we view them under the same circumstances, would be identical in character with what are seen upon the moon. The most remarkable case of this similarity is offered by a certain tract of volcanic area near Naples. The resemblance is brought out very clearly in our illustration. The difference is in magnitude. None of the craters of the district in Italy referred to exceed a mile in diameter, while many of those upon the moon are sixty and seventy miles in diameter.

When we turn our attention to the lunar mountain

ranges we find that, in comparison with the craterial formations, they are decidedly few. The most important ranges upon the moon occur in the northern half of the visible hemisphere, and where the craters are fewest. The finest range is that named after the Apennines. It extends for about 450 miles and has been estimated to contain 3,000 peaks, one of which attains the altitude of 18,000 feet. Isolated peaks are found in smaller numbers. The best known of these is Pico, which rises abruptly from a generally smooth plain to a height of 7,000 feet.

REVIEW OF FACTS RELATING TO THE MOON.

The moon is about 240,000 miles distant from the earth; in bulk the earth is eighty-one times as large as the moon; the diameter of the moon is 2,163 miles.

The moon revolves around the earth once in twenty-seven days, eight hours, but it requires twenty-nine days twelve hours to reach the same relation to sun and earth or to pass from one new moon to the next new moon. This is called the lunar month. The moon moves from west to east; this accounts for its rising later each evening.

The moon always presents the same hemisphere to the earth; it shines by reflecting the sunlight; the earth is its moon, and when the moon is " new," the dark portion is seen to be dimly lighted by the earth-light.

The moon is a dried-up world without atmosphere, water, or vegetation. Its surface is covered with mountains, plains, and hundreds of crater formations.

The moon's day and night are each about fourteen days long. The night must be intensely cold, and the day intensely hot.

The common notions connecting the moon with changes of weather, favourable seasons for seeding, etc., are without scientific foundation, and are classed as the merest superstitions.

IV. THE MOON.

BY WALTER CHARLES LOCKYER, B.A.

Student of Astronomy, Greenwich Observatory, England.

Fourth Paper.

ECLIPSES.

ECLIPSES, like comets, have always been interpreted by uncivilised and superstitious people as indicating calamity of some kind, and like comets, too, they are visible at such irregular intervals as to excite the greatest curiosity and interest among intelligent people.

The moon is much closer to the earth than is the sun, and when the moon comes between us and the sun we have an eclipse of the sun—that is, the sun is hidden, or partly hidden, from our view by the moon. Then again, our moonlight is simply reflected sunlight, and when the earth passes between the sun and the moon, it shuts off the sun's light from the moon. This we call an eclipse of the moon.

The calculation of an eclipse of the moon presents fewer complications than that of an eclipse of the sun, since for the former we have only to indicate the general circumstances of the phenomenon, which are the same for

all observers, while for the latter the indication of the general circumstances is far from sufficing, on account of the differences of aspect, according to the region, and the narrowness of the zone in which the eclipse is central.

The ancients predicted eclipses of the moon with a fair degree of accuracy, relying as they did on the fact that they occur with a certain degree of regularity—that is, with the same interval between them—in the course of

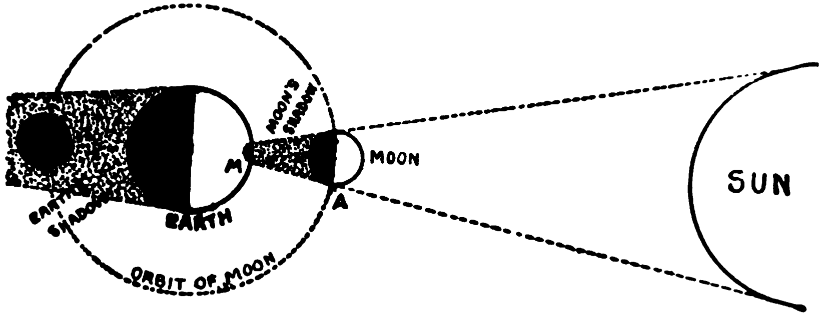


FIG. 1. ECLIPSE OF THE SUN.

eighteen years, eleven days; so that it was sufficient to have registered the eclipses of the moon for this period of time to predict accurately all succeeding eclipses. It is possible, however, with our precise knowledge of the heavenly bodies, to calculate for centuries ahead not only the general circumstances of eclipses of the sun and moon, but even the detailed courses of eclipses of the sun. An eclipse of the sun is a very rare event at any given place. The path of an eclipse of the sun may not cross a particular section of country once in a century. Flammarion predicts that a true total eclipse of the sun will not be visible in Paris until August 11, 1999.

Eclipses of the sun always happen at the moment of new moon and eclipses of the moon at the moment of full moon. If the moon revolved around the earth in the same plane as the earth around the sun, it would be eclipsed in our shadow at every full moon, and it would eclipse the sun at every new moon, as may be seen by an examination of Figure 1, page 359. But the moon passes sometimes above and sometimes below the cone

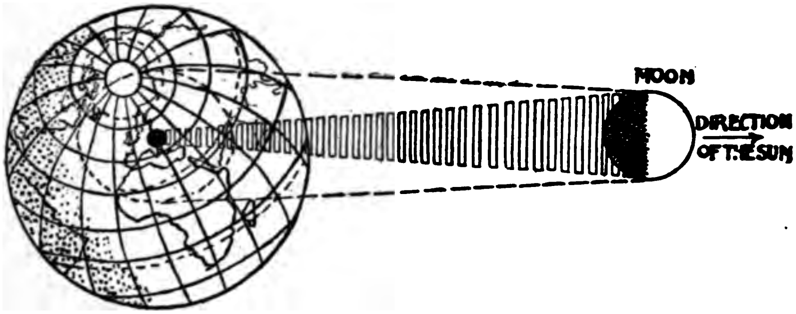


FIG. 2. ECLIPSE OF THE SUN.
(Showing small portion of earth shadowed.)

of the shadow, owing to the slight inclination of her plane to that of the earth. When the moon is at A, and in a direct line between the earth and the sun, she hides the sun totally from a small portion of the earth (M) and partially from a larger portion. This little circle, ninety miles wide, passes along over country and sea, at a rate of more than 1,000 miles an hour, following the motion of rotation of the earth. All the countries over which this shadow passes have the sun hidden during a certain time. It is a *total* eclipse, if the moon is sufficiently near us for its apparent diameter to exceed that of the sun; an ***annular***

eclipse, if the moon is in the most distant region of its orbit and is smaller than the solar disk; a *partial* eclipse, if the centres of the moon and sun do not coincide.

The earth throws behind it, opposite to the sun, a conical shadow, which ends in a point at a distance of about 857,000 miles from the earth. At the mean distance of the moon (238,000 miles) the shadow of the earth is a little more than twice as wide as the moon. When the moon passes through this shadow it is eclipsed.

THE TIDES.

We have already seen that Newton formulated a law which states that every body in nature attracts every other body with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between them, and the direction of the force is in the line joining the centres of the bodies. It is to this law of gravitation that we must turn for an explanation of the manner in which the tides are caused. In the particular application of Newton's law under consideration, the two bodies between which the gravitational stress is set up are the moon and the earth. The earth attracts the moon and the moon attracts the earth. The earth includes two parts of very different physical properties; these are the solid earth and the water of the oceans. The solid earth can only move as a whole, but the waters over the earth can move independently.

The explanation is simplified, if we suppose that the earth is at rest and completely covered by an ocean. Upon the side of the earth nearest the moon the waters

are drawn away from the earth toward the moon—that is, they are bulged out, as it were, toward the moon, thus increasing their depth. The earth is at the same time drawn toward the moon and away from the waters upon the opposite side. This accounts for the fact that we have high tides upon opposite sides of the earth at the same time. Such is a very general explanation of what is known as the equilibrium theory of the tides.

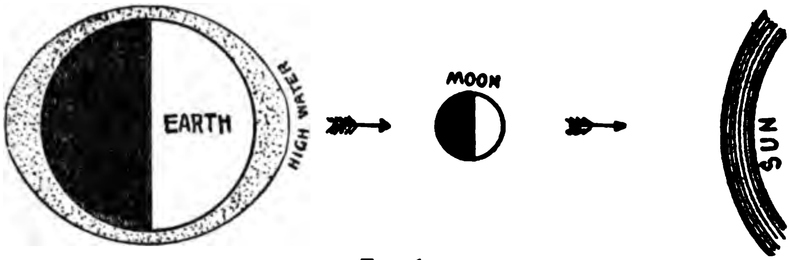


FIG. 3.
(Illustrating the cause of the tides.)

We have two tides during the time in which the earth makes a complete rotation relatively to the moon—that is to say, in a little less than twenty-five hours—consequently, if we have high tide one day at 9 o'clock in the morning, the second high tide will occur about 9.30 in the evening, and the next about 10 o'clock the next morning.

The sun produces a similar effect on the waters of the sea, but the enormous mass of that body is more than compensated by the great distance at which it lies from the earth, so that the tide due to the action of the sun is much smaller than that due to the action of the moon. In the general phenomenon of the tides, the moon is responsible for two-thirds and the sun for only one-third. The

highest tides are those which occur at the new moons and full moons, for then the actions of sun and moon cooperate, while at the quadratures they are exerted at right angles to each other.

We have seen that the differential attraction exerted by the moon upon the ocean waters and our solid globe causes a hump of water to exist under the moon and upon the opposite side of the earth. If the moon revolved around the earth in the same time that the earth takes to make a complete rotation, the projection would always have the same position; but since the earth rotates under the water pulled into a heap by the moon, a tidal wave is produced. There is thus a drag on the earth as it rotates, which tends to decrease the rational velocity, and therefore to increase the length of the day. This scientific theory is set forth by Professor Simmons, of the Royal College of Science, London, in the following paragraph:

"Ages ago the day was only three or four hours long and the tidal action of the moon has increased it to the present value. In those days the earth and moon were very close together. The revolution of the latter took place in exactly the same time as a rotation of the former; in fact, the two bodies moved as if they were rigidly connected face to face. As the day increased in length the month increased also. A condition was eventually reached when the moon revolved once in twenty-nine terrestrial rotations. At the present time the moon revolves round the earth in twenty-seven and one-fourth days. The month and the day will in the future tend toward equality of length and finally will be equal to one another. When this happens the month and the day will be fifty-seven times as long as the day as we know it. To sum up, by tidal action the velocity of the earth's motion of rotation is being constantly decreased and the moon's motion is being accelerated. The moon's distance also tends to decrease. The total tendency is to increase the length of the day and the month as we now know them."

Mr. G. H. Darwin, son of the eminent naturalist, has calculated that 54,000,000 years ago the earth's day was only three hours long, and that the constant increase due to tidal action will, in 150,000,000 years, give us a day seventy times as long as at present. At our present rapid rate of multiplying responsibilities, we shall probably need a much longer day in 150,000,000 years.

V. THE FIXED STARS.

By Winslow Upton, A.M.

Sometime Professor of Astronomy, Brown University.

First Paper.

THE CONSTELLATIONS—HISTORICAL.

The science of astronomy had its beginnings in Chaldea and Egypt before historical annals were written. The primitive astronomers of these countries began the work of observation and carried it on so successfully that they understood perfectly well the diurnal motion of the heavens and the annual motion of the sun among the stars, though they did not explain them by the rotation of the earth on its axis and its revolution about the sun. They also perceived and explained correctly the motion of the moon about the earth. These three movements of the heavenly bodies are so evident that we need not be surprised at their perceiving them. But their science advanced to more intricate matters, for they detected the five planets which are readily visible to the naked eye and understood their forward and backward motions as viewed from the earth, though they could not explain

them as we can to-day. They comprehended all these movements so thoroughly that they found their relations to each other, and thus could predict the positions of the moving bodies and also such occasional events as eclipses. For these researches they were obliged to study the arrangements of the stars whose fixed positions gave them reference points to which they could refer the moving planets. Thus they began to classify the fixed stars into groups, and adopted for the system of the classification a division into constellations, which is still in use for purposes of notation.

ORIGIN OF THE CONSTELLATIONS.

The early astronomers had three distinct motives for classifying the stars. The one just named was a purely scientific one—a desire to know how the stars are placed in the sky for the sake of this knowledge simply, and to make it a basis for the study of the motions of the bodies which move among them for the sake of this additional knowledge. A second motive was a practical one—a desire to use the motions for time reckoners. To-day we are following the same plan as that devised by these eastern astronomers. Our calendar, with its subdivisions into twelve months and into weeks of seven days each, came from Egypt and Chaldea, and our subdivision of the circle into 360 parts or degrees, with their further subdivision into sixtieths, is also a part of our inheritance from them. A third motive was an astrological one—a desire to find the influence which the heavenly bodies exerted upon the earth, shown by its climate, and also their

influence upon human life and character. This motive is probably the reason why the astronomers adopted the group system of classifying the stars rather than some other. They selected certain conspicuous configurations, gave to them names derived from their mythology or other sources, and imagined figures of the objects named drawn around the stars of the group. Then they noticed

CHINESE MEDAL SHOWING THE GREAT BEAR.

what occurred on the earth when these groups were in their various positions in the sky or when the moon or planets passed through them. Assuming the relation of cause and effect, they tabulated the positions of the stars and planets, together with the simultaneous occurrences on the earth, and thus derived the precepts of the science. We are interested in this to-day because the pictorial method of classifying the stars was the one adopted, and because it is still used for naming the areas containing the star groups, though all other uses have been aban-

doned. Two important facts should be noted in connection with the origin of the constellations:

1. They were not intended at first as a method of dividing the whole sky into areas. The original constellations were conspicuous groups selected from the celestial sphere for purposes of special study, and there were large gaps between them—the stars which were not in any constellation. Thus the earliest catalogue of stars which has come down to us—that of Ptolemy in the second century of our era—contains forty-eight constellations. The stars in each are given, and then follow the neighbouring stars, which are outside the constellation. More than one-tenth of the stars of this catalogue are in the unclassified lists, among them Arcturus, one of the brightest stars in the sky.

2. It is not to be expected that a resemblance should be discovered between the groups of stars and the objects whose names were selected. It is doubtful if those who gave the names had any thought of such resemblances. In a few cases, where the name given is that of a snakelike figure, like Draco, Scorpio, Hydra, a winding line of stars may be said to resemble the object. Sometimes the number of stars in any group is too small to give the least resemblance to anything but a simple mathematical figure. Ptolemy gives but two stars in the constellation Canis Minor. Where the stars are sufficiently numerous, the resemblance may be sought with better prospect of success, but it is better to regard the groups simply as pictorially named.

THE PRIMITIVE CONSTELLATIONS.

Our knowledge of the exact way in which the early astronomers grouped the stars is quite fragmentary. There are numerous allusions in classical writings to them, so that we know some of the names that were given

ANCIENT HINDOO ZODIAC.

them. The recent study of the tablets of Assyria and of the inscriptions on the temples in Egypt has given further glimpses of the ancient system. But we cannot as yet reconstruct the figures and locate the stars in them. Probably the nearest approach to definite information is given

by the sculptured groups found at Denderah, on the banks of the Nile, which are called the "Zodiac of the Denderah." They are thought by archæological students to represent constellation figures. If this is so, and the identification is correct, our modern constellation, Ursa Minor, the Lesser Bear, was represented as a jackal, and Draco, the dragon, as a hippopotamus, by the Egyptian astronomers who devised the constellation map. Other differences between earlier and later classifications are known to have existed.

It is quite likely that there were a number of classifications made by different astronomers. One, however, has survived in full, and while it does not go back to Chaldea or Egypt, it represents the arrangement which the Greek astronomers had adopted, based upon whatever earlier groupings they had inherited from former ages. Ptolemy's catalogue of stars, prepared in the second century of our era, includes the catalogue of stars which Hipparchus had made in the second century B.C., and it is so arranged, fortunately, that we can reproduce the outlines of the figures and locate them with regard to the stars of the groups. The Greeks had adopted the plan of locating the position of heavenly bodies precisely as places on the earth are located by their latitudes and longitudes. They imagined a system of circles drawn among the stars like our equator, meridian, and parallels, and gave the positions of the stars by their celestial latitudes and longitudes. Modern astronomers use the same plan. In Ptolemy's catalogue each star is designated in two ways—by its position in the figure by which the group is named, and also by its celestial latitude and

longitude. The latter enable us to identify the stars in the group and the former to reproduce the outlines of the figure with some success. Ptolemy's catalogue contains 1,025 stars, of which 917 are grouped into forty-eight constellations, and 108 unclassified.

CONSTELLATION FIGURES.

In the original constellations the figures drawn were all-important, as the individual stars were named from their position in the figure. Now this method has become entirely obsolete and the figures are omitted from many modern star charts. Their historical interest, however, has caused their retention in some publications. As we have no knowledge of the exact way in which the early drawings were made, we can only reproduce the figures in outline from the positions of the stars, and in many cases essential details must be supplied. Thus, if one star determines the position of the head we cannot tell whether the head is to be drawn in profile or full face. In the sixteenth century a German astronomer, Heinfogel, drew the outline figures and secured the aid of the famous artist, Albrecht Dürer, in completing them. His drawings, which are highly embellished, formed the basis of the figures given on globes and atlases until this century. Recent atlases return to the skeleton outlines.

V. THE FIXED STARS.

BY WINSLOW UPTON, A.M.

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Second Paper.

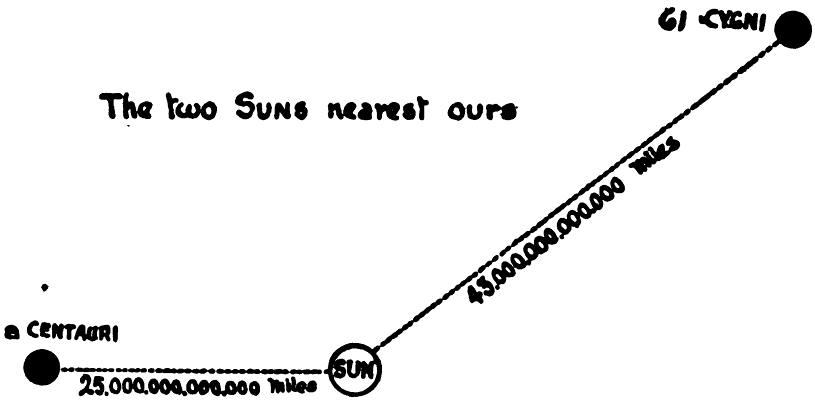
THE CONSTELLATIONS—HISTORICAL.

IN the preceding article it was shown that the constellations were invented by the eastern astronomers, and that our chief knowledge of them comes from Ptolemy's catalogue, prepared in the second century A.D. It was also stated that the design of the inventors of the system seems to have been to designate in this pictorial way the most conspicuous star groups rather than to subdivide the whole sky into areas. Sometimes the constellations overlapped, and there were many large spaces in which there were no constellations drawn, especially where there are faint stars only. The original constellations included the portions of the sky visible from the northern hemisphere only.

THEIR PLACE IN ASTRONOMY.

The position of the constellations in modern astronomy is a very unimportant one, which is the reason why so

little interest is shown in perfecting the system. The astrological motive which prompted the original classification is wanting, and the system of naming the stars by their position in an imaginary figure has been supplanted by a more prosaic but more accurate method. Still, in the advance of a science no one wishes to throw away



Powerful telescopes bring to the observer a hundred million stars—that is, a hundred million suns similar to ours and surrounded by worlds counted by thousands of millions. Light travels at a rate of 186,400 miles a second and reaches us from the sun in eight minutes and thirteen seconds. Notwithstanding this unimaginable velocity, it takes light four years and 128 days to reach us from Centauri, the nearest of the fixed stars. At a constant speed of fifty miles an hour it would take an express train 55,000,000 years to reach this our nearest neighbour sun. Another interesting fact is that both the nearest stars are double. When studying our own solar system it seems as if the sizes and distances were inconceivably great; but, great as they are, the entire solar system is as a mere drop to the ocean when compared with the vastness of the universe of stars.

completely the work of the pioneers, but to adapt it, if possible, to the newer needs. And so the constellation names are retained for the areas in which the old figures are drawn, while the figures themselves are not used.

The leading stars in the sky are lettered or numbered in each of these areas, the Greek letters being usually employed, as suggested by Bayer in the seventeenth century. Thus the pole star is called Alpha Ursæ Minoris. The name of the constellation is usually given in its Latin form, and appears in the genitive case if preceded by a letter or number. A map of the heavens appears very much as a map of the United States in which the country is divided into States of varying size and shape, with the boundaries between them drawn in a way seemingly capricious but really the result of the growth of the system of subdivision.

The number of the constellation areas now included in star atlases is between eighty and ninety. It includes the forty-eight given by Ptolemy, with the additions proposed by later astronomers, chiefly Hevelius, Bayer, and Lacaille. The discrepancies in the different atlases are chiefly in the southern sky. Eighty-eight groups are generally recognised, and this may be regarded as the number of the constellations.

SHOULD THE CONSTELLATIONS BE STUDIED?

A knowledge of the constellations in the sense of ability to trace the classic figures is no part of modern astronomy, while still interesting to the student of the history of the science or to one seeking to understand the numerous allusions to them in literature. But a knowledge of the configurations of the sky will always be a part of the science of astronomy, and as the heavens are divided into

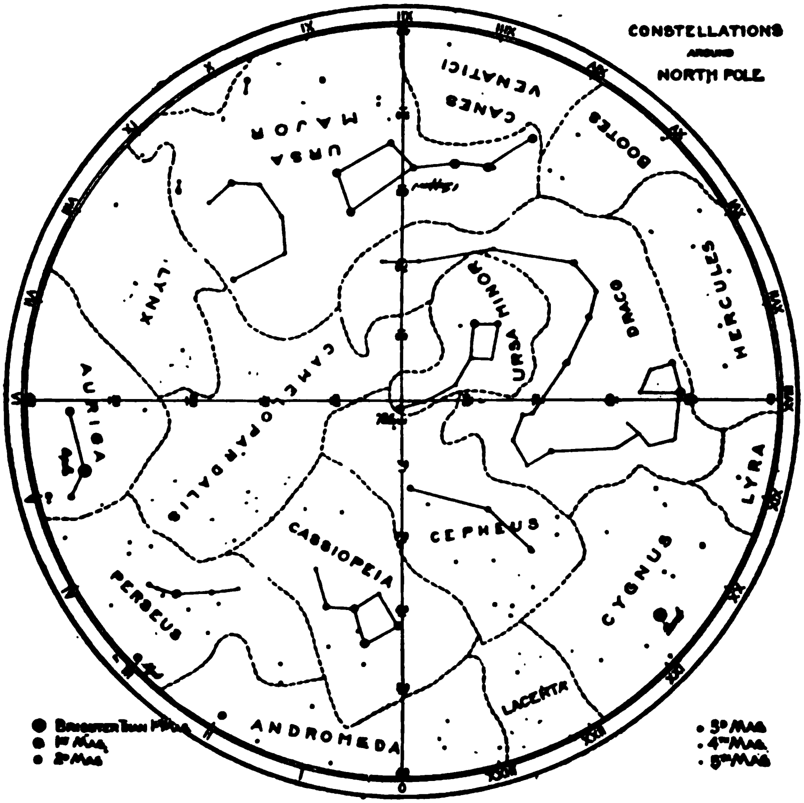
areas, bearing the old constellation names, the student of this part of astronomy will find it necessary to learn the names and identify the stars within them by their characteristic groupings. The leading areas have each peculiar arrangements of the stars, usually geometrical, which are readily discerned. Thus the characteristic figure of Leo is the curve of stars resembling a sickle, and also a right-angled triangle of three bright stars east of the sickle.

The advantage of familiarity with the star groups is that we can better understand the movements of the heavenly bodies. When a few leading groups are mastered, and are watched from time to time, the following important teachings, among others, will be illustrated:

1. That the earth turns on its axis once in about twenty-four hours. It will be seen that the stars move steadily across the sky from east to west, just as the sun does.

2. That the time of rotation is less than twenty-four hours. This is evident by noticing that any group is a little farther westward on any night than it was the preceding night. After two weeks it will be found to reach a given direction a whole hour earlier, hence the gain is about four minutes each day. The time that the earth turns on its axis is really 23 hours 56 minutes.

3. That the axis on which the heavens seem to turn is inclined to the place where we stand. All the paths of the stars are circles tipped up as we view them. A star which rises in the east and sets in the west does not pass through the point overhead, but much farther south. The star which does pass overhead, like Capella or Vega, rises in the northeast and sets in the northwest. The



CONSTELLATIONS AROUND NORTH POLE

stationary point where the axis terminates is found to be not far from the star known as the pole star for this reason.

4. That the earth moves about the sun once a year. As we are unconscious of our motion, this shows itself as a motion of the sun among the stars completely around the sky once a year. The glare of sunlight prevents our seeing its actual path as burned among the stars, but the setting stars disappear earlier and earlier each successive night, and those passed by the sun rise earlier and earlier each morning. The ancients used these motions for their calendar. Thus the first appearance of the star Sirius in the early morning before the sun warned the Egyptians that the season had arrived when the overflow of the Nile was to be expected.

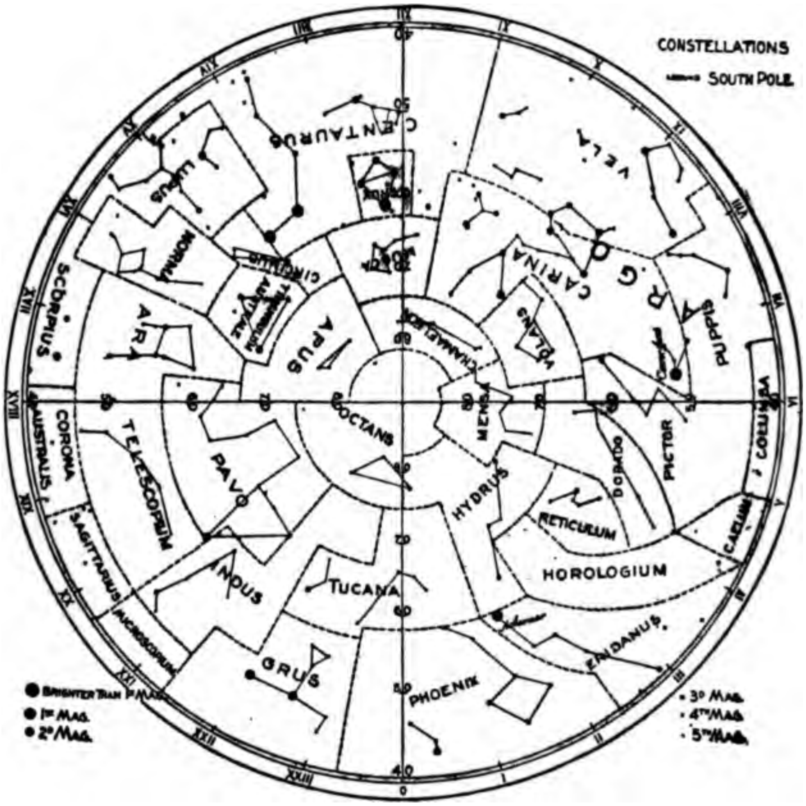
5. That the moon and planets move in about the same paths among the stars—the former moving steadily eastward among the stars, while the latter move eastward for a part of the year and westward for a part.

In short, the chief facts of astronomy, which are so hard to comprehend when read from a book, become living realities when traced out among the stars.

THE STUDY OF STAR GROUPS.

The study of star groups requires a good atlas and much patient individual work. Hints for its successful prosecution are given in many treatises. The following are emphasised here:

1. Make the study systematic by following a definite


CONSTELLATIONS
SOUTH POLE
BRIGHTER THAN 1st MAG.
1st MAG.
2d MAG.
3d MAG.
4th MAG.
5th MAG.

plan. A haphazard identification of a few groups will soon be forgotten.

2. An orderly method of procedure would be one like the following:

(a) Begin by facing the north on any clear night in the year. Find first the seven stars known as the dipper, but which are the characteristic stars of Ursa Major. Then follow around the pole, finding the characteristic groups in the constellations Draco, Cepheus, Cassiopeia, Ursa Minor.

(b) Learn the zodiacal groups which are visible. They form a band extending around the sky, in which the sun, moon, and all the visible planets move. Each has a good distinguishing group, rather faint in Pisces and Cancer, but conspicuous in the others. The atlas will give their positions regarding the constellations in the north first learned. The twelve groups are Pisces, Aries, Taurus; Gemini, Cancer, Leo; Virgo, Libra, Scorpio; Sagittarius, Capricornus, Aquarius. The separation into four divisions shows the groups through which the sun passes in spring, summer, autumn, and winter respectively. Usually five of these groups can be seen at any time, and the order is from west to east.

(c) After these groups are recognised, add the principal groups between them and the northern groups first mentioned, then those south of them to the southern horizon.

3. Learn the important groups first and the characteristic stars in each group, leaving out the minor groups and also the fainter stars in the leading groups.

4. Notice the appearance of the groups in their various positions in the heavens, such as rising, culminating, and

setting, so as to be familiar with them in their varying aspects.

5. The connecting of stars by imaginary lines, so as to bring out the characteristic shapes of the group, is a great help in learning them.

VI. COMETS AND METEORS.

By Charles H. Churchill, A.M.

Sometime Professor of Astronomy, Oberlin University.

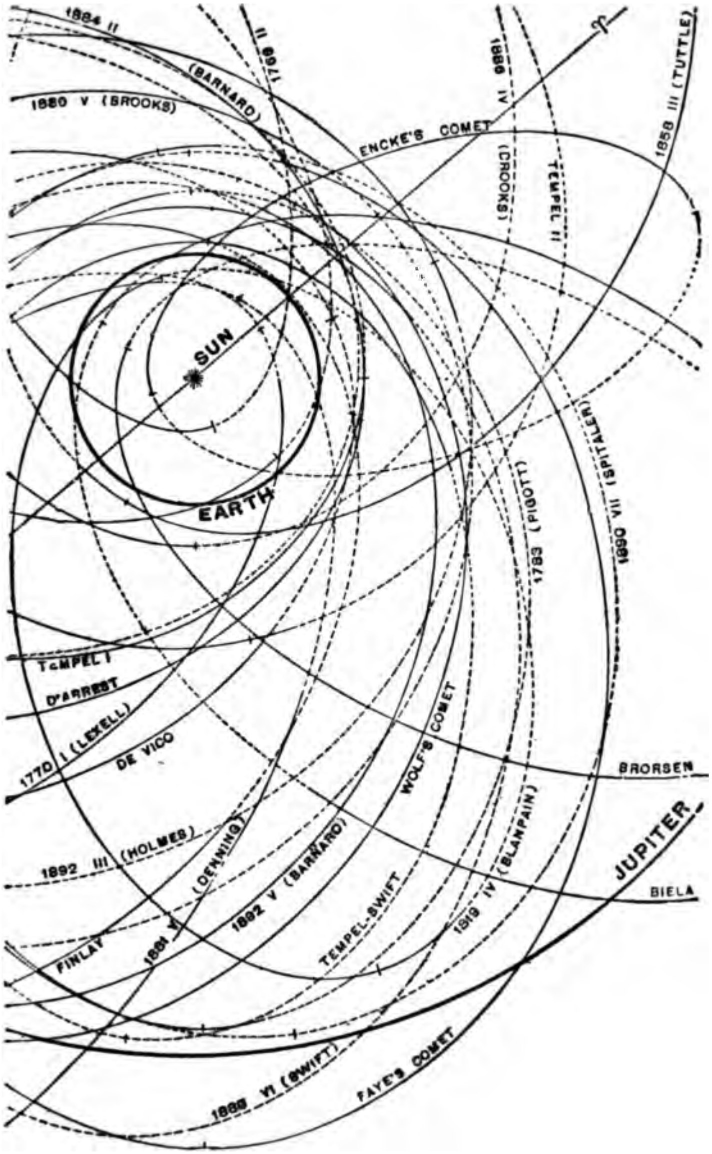
COMETS.

The typical comet has three distinguishing features—the nucleus, the coma, and the tail. The nucleus is a bright point, more definite and of greater density than any other part of the comet. Its path in the heavens is regarded as the comet's orbit. The coma appears as a light cloud surrounding the nucleus. The nucleus enveloped in the coma constitutes the comet's head. The tail is merely a continuation of the coma, a long streamer of light, always extending away from the sun, whatever be the direction of the orbit.

One of the unsettled questions concerning comets is their exact weight and density. Extreme limits have been assigned by different scholars, according to their point of view, or possibly their temperament. Thus Professor Tyndall said of a great comet that, judging only by its light, all the material of it might, if condensed to the specific gravity of gold, be easily carried in a lady's reticule. His experimental proof was to confine a mere trace of gas in a large glass tube, through which, in a

darkened room, a small current of electricity was passed. The gas was gradually illuminated to so surprising an intensity as to excite the greatest admiration and enthusiasm. Professor Tyndall's conclusion seemed the most natural one possible. On the other hand, Professor Pierce of Harvard judges that such a comet might weigh twenty million million tons. This question of density is happily disposed of by Professor Young, who proves that even if the mass exceeds somewhat the estimate of Professor Pierce, the mean density is less than one-seven-thousandth that of the air at the earth's surface, " much lower than that of the best air-pump vacuum."

Even the head of a comet, when covering a fixed star, does not sensibly diminish its lustre. This is conclusive as regards the extreme rarefaction of the mass; but when we consider the vast dimensions of comets, we shall not hastily conclude that they are of little weight. The comet of 1882 had a volume at least 20,000 times that of the sun! Yet, at the mean density given above, it could not disturb the smallest visible satellite. At a distance of 293,000 miles it would draw our moon from its orbit only one twelve-hundred-thousandth of an inch the first second. The motion would be imperceptible, even if the force continued to act at that distance a long time. On the other hand, the comet itself is drawn so far out of its path by a small satellite that its period is subject to great changes by reason of disturbing influences of this character. Nearly all the periodic comets are associated more or less intimately with certain of the planets. Thus we have the Jupiter comets, sixteen in number; Saturn has a group of two, Uranus three, and Neptune six. This



JUPITER'S FAMILY OF COMETS.
(From Payne's "Popular Astronomy.")

indicates the method by which many comets may have been added to the solar system. The sun, with his great train of attendants, moving majestically into open space in a nearly straight course, at the rate of twenty miles a second, will occasionally come to a region of the nebulous bodies known to be scattered through these solitudes. Powerless to resist, the flocculent mass yields to his attractions and makes haste to join his retinue.

Besides, not all that enter the system remain. They enter at all possible angles with the ecliptic, and so may or may not come anywhere near the dangerous planets. Comets from the north or south, approaching close to the sun in parabolic paths, would be in no danger whatever from such attractions. They would rush around him and be off with wonderful speed, never to return.

When a nebulous mass has once come fully under the influence of the sun, its history becomes exceedingly interesting. Its irregular, or possibly globular, form, of enormous extent, becomes elongated. Small, dense masses of stone or iron scattered through it at intervals of several hundred miles, move in converging lines, and with their gaseous envelopes soon form the nucleus and coma. The remainder of the gases and solids form the embryo tail. As the nucleus draws nearer the sun, new and wholly unexpected phenomena appear; the coma, though hotter, seems to grow smaller; from the most heated parts of the comet's nucleus jets of incandescent gases are seen to pour forth directly toward the sun, and, after moving a few thousand miles in that direction, to bend suddenly back and hasten to add their volume and brilliancy to the train; brilliant surfaces boil up in succes-

sion from the nucleus, and in a few hours push outward like vast bubbles. It is a battle of the giants—heat, gravity, and electricity in open warfare. Heat forces out the gases. Electricity acting at the surface only would not check the momentum of the principal mass, but its repulsion sweeps back the infinitely attenuated gases of the outer envelope, acting especially on the sun-exposed end of the comet. These electrified gases entangle those at the surface of the coma and diminish its apparent size. The same process continues while the comet is backing away on the return branch of its orbit, until it reaches a region too cool to longer hold the masses to their gaseous form.

METEORS.

In the solar system we have not only the sun, the planets, and their satellites, the hundreds of asteroids, the zodiacal light, and the periodic comets, but we have an unnumbered host of other bodies, called shooting stars, meteors, aerolites, bolides, etc. These are all meteors, but classed partly by their motions and conditions and partly by difference of materials. Of the number of shooting stars visible which enter our atmosphere every twenty-four hours careful estimates give at least 7,000,000. Of those still smaller there are doubtless many millions more. Their motion is from all directions, and they seem to have no bond of union. They owe their light and heat to the friction with the air and to the sudden arrest of momentum. They are first seen at about seventy miles altitude and disappear at fifty. Their cal-

culated weight varies from 1 to 100 grains, according to brightness; their light varies from that of the faintest fixed star to that of Venus or Jupiter. They finally become mingled with our atmosphere in the form of impalpable dust or of gas. Some observers have suggested that they supply the air with the carbonic acid gas which vegetation continually withdraws.

When a shooting star is heavy enough to penetrate the air and reach the earth, it is called par excellence a meteor. Various circumstances accompany its flight and fall. Its surface becomes intensely heated and luminous; brilliant scales are thrown off, leaving a long train of light. In some cases the noise of this incessant bursting is heard distinctly by observers fifty miles distant. Frequently the meteor moves nearly parallel with the earth's surface, and so continues its flight and its roar for many hundreds of miles. It makes zigzag motions, and has sudden changès of brightness, and disappears with an explosion. Such meteors are called bolides. Hundreds of large meteors have been seen to fall and reach the earth. They differ greatly in their composition, though they are all of earthly elements. Those called aerolites are of common stone. About a dozen in all of those seen to fall are of iron. Hundreds found on the earth, though not seen to fall, are treasured as iron meteors, which doubtless they are. The stone meteors are likely to fall in fragments, sometimes distributed over large areas, while the iron meteors are usually single and their surfaces, though indented (pockmarked), are highly polished. Even the stone meteors contain as high as thirty per cent. of iron, and the iron ones have peculiar combina-

tions of bismuth or nickel, not found in the earth's iron ores. (The number of these large meteors is very small compared with that of the shooting stars, not more than one in hundreds of millions.)

METEORIC SHOWERS.

But the greatest interest centres in the wonderful meteoric showers which come periodically, and which have in some cases a remarkable history. The shower of November 13, the Leonids, was seen by Humboldt, on the coast of Mexico, in 1799. It returned in 1833 and 1867, re-appearing again in 1899. It is observed that after thirty-three years the phenomenon is repeated in each of the two following years, but with diminishing splendour. The earth in its orbit arrives at the denser portion of the meteor swarm, through which it drives in a few hours. The length of the swarm extends to about one-tenth of its whole orbit, hence the earth, at yearly intervals, can plunge through it three times before it has all passed the point of intersection. This shower was witnessed by Humboldt in Mexico on the morning of November 13, 1799. Again, by American and British astronomers, November 12, 1833. It was this latter return which fixed its period and greatly excited the astronomers of all countries. Then it began to be suspected that the Leonids were the remains of a lost comet! Olmsted said that the earth was passing through a comet! Erman and Newton predicted the return of the meteors in 1866.

Schiaparelli of Milan, and Secchi, studying on the August shower of meteors, proved that they were mov-

ing in the very path of Tempel's comet of 1862. About the same time Leverrier gave to the world his calculated orbit of the Leonids, Oppolser published the result of his study of the orbit of Tempel's comet of 1866. This was found to be identical with the path of the Leonids, and the two great questions were answered for all time—namely: What becomes of the comets? And what is the origin of meteor swarms? Since that time a hundred different swarms have been discovered, and in many cases the comets which gave them birth have been pointed out. The single meteors and shooting stars are the scattered material from the trains of comets of all ages, lost in hastening around the sun or in passing near the planets and satellites. Jupiter is a perfect comet trap, and the other planets are the same with less power. Fragments which are drawn to any of these bodies are simply added to their mass and lost to view forever. But the great majority of them still drift in space. The air acts as a buffer to defend us from what otherwise would be a dangerous and perpetual bombardment. Thus the long history may be compressed into a single view. First appears a far-away nebula, then for centuries a comet, next an untold number of tramp as well as regular meteors of every size and density. Finally falling to the sun or to a planet, a satellite or an asteroid, prolonging the light, heat, and stability of all till they disappear and are lost to view forever.

VII. NEBULÆ.

By William Henry Pickering, S.B.

Professor of Astronomy, Harvard University.

The word nebula means a cloud. It was originally applied to all faint, hazy bodies in the stellar system. By means of powerful telescopes it was found that many of these bodies were composed of great numbers of stars placed close together. These were called resolvable nebulæ, and it was supposed at that time that all nebulæ could be so resolved, if our telescopes were only sufficiently powerful. About thirty years ago it was shown independently by Secchi and Huggins that when the light from certain nebulæ was viewed through a prism the image did not show a continuous band of coloured light, as the light coming from a piece of white-hot iron would do, but was broken up into separate coloured images. The three most conspicuous of these images were green and blue. The instrument that they used is called a spectroscope. Now it is known that this effect can be produced only by a luminous gas. The conclusion was therefore inevitable that these particular nebulæ were huge masses of luminous gas, and therefore never could be resolved into stars, although a number of stars might

be scattered through them. Astronomers, therefore, had to change their definitions, and what had heretofore been called resolvable nebulæ were now called clusters, while the name nebulæ was reserved only for those bodies which the spectroscope showed to be composed mainly of gas.

Several nebulæ have been suspected of marked changes in their appearance. There is a small nebula in Taurus, which is sometimes visible in small telescopes, and sometimes cannot be seen even with our largest instruments. Changes of shape have been suspected in the great nebula in Orion, in the great nebula in Carina, in the Omega nebula in Sagittarius, and in the Trifid nebula in the same constellation; in fact, in most of the irregular nebulæ that have been best studied. The Trifid nebula contains three narrow, dark, curved lines, which meet at a point. At the beginning of the present century a well-known triple star was situated exactly in the middle of one of these lines, according to Herschel and other astronomers. It is now certainly in the edge of the nebula itself. We know that the star has not moved, as compared with the other stars around it. The change must therefore be in the nebula.

It is generally admitted that the whole solar system was once a vast, whirling, nebulous cloud, that most of it condensed to form our sun, while a small fraction of one per cent. of it was left on the outside to form the various planets and satellites with which we are familiar. Of the outside portions a small fraction of one per cent. concentrated to form our earth and moon, which later separated into two parts, thus forming a double planet as we now find them. Unlike the earth, the larger planets threw off

rings as they cooled and diminished in size, and these rings, most of them, later broke up into pieces, which joined together to form the satellites by which all the larger planets are surrounded. The little moons of Mars were perhaps originally asteroids, but it is very certain they could not have been formed in the same manner as were the other satellites.

Nebulæ may, for convenience, be divided into five classes—(a) diffuse, (b) irregular, (c) spiral, (d) ring, and (e) planetary nebulæ. The diffuse nebulæ are usually faint, of irregular shape, and have little or no definite internal structure. They are very numerous, but of less interest to the average observer than the other kinds. Many of them are found in the constellation Virgo.

The most magnificent object in the whole stellar universe—the great nebula in Orion—belongs to the second class. It is just visible to the naked eye as a faint, hazy object in the sword handle, a few degrees below Orion's belt. An opera or field glass shows it much more clearly, and even a small telescope will show that it is a comparatively large object. To be seen at its best, however, it should be viewed through a large telescope in the tropics, where the clear atmosphere permits us to see distinctly portions of its surface never visible in these latitudes. Under these circumstances it is seen to cover a rather larger area of the sky than the full moon, while another bright nebula of about one-quarter its size is seen nearly touching it to the north. The whole area is filled with the most wonderful detail of irregular billows of gas, some like little wisps of cloud and others so bright as to look almost like solid masses, but all of the most fantastic

forms. In the brightest region of all shine six stars, so close together that in an opera glass they appear as one. There is really a seventh star in their midst, but it is so faint as to be visible through only the very largest telescopes.

But perhaps most wonderful of all, when we consider to what it leads, are the revelations of photography. The nebula was first photographed by Dr. Henry Draper of New York, in 1881. Seven years later it was photographed at Harvard Observatory, showing distinctly large areas that had only been vaguely suspected in the visual observations of previous astronomers. Finally, in 1890, the Harvard observers, located at a temporary station upon Mount Wilson, in southern California, by means of a continuous exposure of over six hours, succeeded in photographing an extension of the nebula never previously suspected, which, in the form of a huge spiral structure, covered an area of some fifteen degrees in diameter. Excepting the Milky Way, this is by far the largest nebula known to exist in the heavens. It is so faint that it never has been, and almost certainly never will be, visible to human eye. Even the sensitive photographic plate can only show its outline under the most favourable circumstances, and until very recently no other observatory had succeeded in photographing it. Latterly, however, Dr. Barnard, who was at that time at the Lick Observatory, succeeded in obtaining a negative fully confirming the Harvard result.

To convey an idea of the size of this object it is useless to attempt to give its dimensions in miles. The unit usually used by astronomers is the light-year. We know

From "Flame, Electricity and the Camera," by George Iles.

THE NEBULA IN ORION.

Photographed at Lick Observatory, November 16, 1898.

if a cannon is fired that the sound will traverse a distance of 1,100 feet in about one second. The light of the flash travels far more rapidly, for it travels nearly 200,000 miles in the same time. To express it another way, it would go around the world nearly eight times in one second. It takes a little over a second for light to reach us from the moon. If the sun should be suddenly blotted out, it would still shine upon us for eight minutes after the catastrophe. This seems a long distance, but it is too short for us to use in dealing with the stellar universe. The unit of distance used by astronomers is the total number of miles that is traversed by light in one year. It is expressed arithmetically by a six followed by twelve zeros. This distance is called a light-year. The distance of the nearest fixed star is about four light-years. The distance of the great nebula in Orion is probably about 1,000 light-years, so that it appears to us, not as it really is to-day, but as it was in the year 900 A.D., or a century before the birth of William the Conqueror. The diameter of this nebula is one-quarter of its distance from us, or about 250 light-years.

In addition to the Orion nebula, there is one other that is about equally visible to the naked eye. This is the great nebula in Andromeda. Several years ago it was shown by Mr. Roberts of England to belong to the well-marked class of spiral nebulæ. Its light, however, is not like that which comes to us from the nebula in Orion, but when seen in the spectroscope is found to consist of a continuous band of colour. It may therefore be composed of compressed gases or of innumerable white-hot solid or liquid bodies. That it is in part composed of these latter,

is indicated by the fact that a few years ago a bright star suddenly appeared in its midst, in a few months vanished, and never has been seen since. This would lead us to believe one of the innumerable host composing this distant system had suddenly brightened, and later had faded out again, as other stars have been known to do in other parts of the heavens. Another very celebrated spiral nebula is that in Canes Venatici.

The best known of the ring nebulæ is that in the constellation of Lyra, but a much more beautiful example is to be found in the constellation Hydra. In this instance, as is frequently the case, the ring is particularly brilliant at two points upon opposite sides. The whole is inclosed in a luminous circle of nebulous matter, and in the exact centre is a small but brilliant star.

The planetary nebulæ are not very interesting objects as seen in the telescope. They are small and round like a planet, hence their name. In some cases they are so small that we cannot distinguish them from a star, as far as their appearance goes, but the spectroscope tells the tale and shows that they are composed of masses of gas. In 1892 a bright star burst out in the constellation Auriga that never had been seen before. A few months later it faded away again, but in its place was left a new planetary nebula. The star had, of course, been there all the time, but was so cold and faint that it had not been discovered until the great explosion made it visible to us. Then, as the gases gradually settled back again into place, they took the characteristic nebular form. Hot gases are constantly bursting out of our own sun in the same manner, and once every eleven years they come out in particularly

violent explosions, but until the sun's surface gets much colder and stiffer than it is now, as may be the case a few million years hence, there is no danger of such a terrific explosion as that which wrecked the distant star in Auriga.

NATURE QUESTIONS OF INTEREST.

By Professor Clinton H. Currier,

Brown University.

Note.—The following questions are given as an indication of the sort of knowledge a reader should be possessed of who has carefully read the Ten Minute Talks in this book. Our readers are recommended to write out answers to the questions, doing the work as accurately and as neatly as possible. Afterwards compare answers.

1. What insects live in colonies? Are these colonies permanent? Page 66.
2. In what way are the bumble-bees beneficial insects? Page 69.
3. What animal illustrates by its life history the evolution of land forms of life from aquatic forms? Page 82.
4. What insect is so prolific as to be capable of producing thirteen generations of over ten sextillion individuals in a year? Page 112.
5. What does the geologist mean by the glacial epoch? Page 131.
6. How have we obtained our knowledge of the plant and animal forms which existed in former geological periods? Page 163.
7. How are some animals protected from their enemies by their colour? Page 174.
8. What are the two kinds of volcanoes? Page 188.
9. What is the origin of the word volcano? Page 186.
10. What is the "lake of fire" in Hawaii? Page 192.
11. What are some of the practical applications of astronomy? Page 194.
12. How is the error of a clock determined by observations of the stars? Page 200.
13. Of two cities not on the same meridian of longitude which will have the later local time, the eastern one or the western one? Page 203.
14. What is the international date line? Page 206.

15. What is the difference between Greenwich time and Eastern Standard Time, used in the eastern part of the United States? Page 207.
16. What important geological product is of vegetable origin? Page 208.
17. Name the different links in the chain which connects the growing forests of the carboniferous age with the graphite deposits of today. Page 222.
18. How many of the planets were known to the ancients and how many have been discovered since 1700? Pages 223 and 225.
19. What planet was discovered as the result of a mathematical calculation? Page 225.
20. How are stellar photographs made? Page 227.
21. What is the modern method of planet-hunting? Page 228.
22. Why is the latitude of a point on the earth's surface believed to be continually changing? Page 232.
23. Why has the photographic plate replaced the observer's eye in many branches of astronomical work? Page 227.
24. Name the members of the solar system. Page 251.
25. How is the maintenance of the sun's heat explained? Pages 256 and 300.
26. What is the peculiarity of the rotation of the sun on its axis? Pages 259, 287, 298.
27. Which of the planets have phases like the moon as seen through a telescope? Page 264.
28. What planets always turn the same face to the sun? Page 265.
29. How does the "year" on Neptune compare with that on the earth? Page 266.
30. Of what are the rings of Saturn composed? Page 268.
31. Why does a comet develop a tail as it approaches the sun? Page 270.
32. What is the probable temperature of the sun? Page 277.
33. How does the astronomer determine the presence of iron in the sun? Pages 259, 278.
34. What part of the sun is visible for only a few minutes at a time? Page 291.
35. State two of Kepler's laws of planetary motion. Page 306.
36. How long would it take a fast express train to cover the distance from the earth to the sun? Page 310.
37. Which of the planets has the greatest density and which the least? Page 313.

38. Would a body, if weighed by a spring balance, weigh the same on Jupiter as on the earth? Page 313.
39. What planet probably has the greatest range in temperature? Page 314.
40. What planet has a satellite which rises in the west and sets in the east? Page 323.
41. What planet has polar caps, which appear and disappear with the seasons? Page 329.
42. Why is the dark portion of the moon dimly visible a few days after new moon? Page 339.
43. How does the date of Easter depend upon the phases of the moon? What is the earliest possible date for Easter and what is the latest? Page 340.
44. Why does the moon rise later each evening? Page 356.
45. What causes an eclipse of the moon? Page 358.
46. What is Darwin's theory of tidal friction and its effect upon the length of our day? Page 363.
47. What unit is used in measuring the distances to the fixed stars? Pages 373, 393.
48. What is a constellation? How many constellations are there? Page 374.
49. If a star rises at 7 P.M. tonight by standard time, at what time will it rise tomorrow night? Page 375.
50. Do the sun, moon and planets all appear to move in the same direction among the stars? Page 377.

ANSWERS.

BY PROFESSOR CLINTON H. CURRIER.

1. The most notable of such insects are the bees, ants and wasps. The colonies of the honey-bees and of the ants are permanent.
2. As pollen-carriers for plants they do good service for mankind.
3. The frog in its development from the tadpole.
4. The plant louse or "green fly" which does so much damage to house-plants.
5. A time in the remote past when the earth's surface was covered by sheets of ice, flowing in glaciers.
6. Largely by means of fossil remains found in the various strata of the earth's surface.
7. In many cases the colour is like that of the ground on which they live which enables them to escape notice.
8. Those with low, flat cones (the true lava type) and those possessing steep cones, the explosive type.
9. One of the few volcanoes mentioned in ancient literature is Vulcano, represented in the myths of old as the workshop of the god Vulcan. Hence the name volcano.
10. A central pit in Kilauea, the chief of the Hawaiian volcanoes, which is an ever seething caldron of molten rock.
11. The three most important practical applications are (*a*) the determination of latitude and longitude lines on the earth, (*b*) the determination of the position of a ship at sea and (*c*) the furnishing of correct time.
12. The astronomer observes through a small telescope called a "transit" the time by his clock at which a certain star crosses his meridian. The difference between this time and the time at which the star should cross as given in astronomical tables gives the error of the clock.

13. The eastern city always has later time.
14. The international date line is an arbitrary line in the Pacific Ocean following very nearly the 180th meridian from Greenwich. Ships crossing this line from east skip one day in so doing, but when a vessel crosses the line from the western side it counts the same day twice over.
15. Greenwich time is five hours later.
16. Coal, which is the resultant of a series of changes which have taken place in beds of vegetable remains.
17. The order is: growing forests, peat, brown coal, bituminous coal, anthracite and graphite with numerous intergrading variations.
18. Mercury, Venus, Mars, Jupiter and Saturn were known before 1700. Uranus, Neptune and nearly a thousand small planets or asteroids have been discovered since that time.
19. The discovery of Neptune in 1846 was due to the calculation of the French astronomer Leverrier. The actual discovery was made by Galle, who found Neptune within one degree of the predicted place.
20. The photographic plate is substituted for the human eye at the eye end of the telescope. The telescope is moved by clock-work so as always to point at the same group of stars as they move across the sky.
21. By photographing a region of the sky. If the telescope is carried along by clock-work at the same rate at which the stars move, the stars register as dots on the plate while the planets which are moving among the stars make short lines on the plate.
22. Observations show that the axis of rotation of the earth is continually shifting its position within the globe. This produces slight variations in latitude.
23. By means of long time-exposures a faint object which is not visible to the naked eye can be photographed. Many discoveries have been made in this way.
24. The solar system consists of a central sun, a group of four inner planets (Mercury, Venus, the Earth and Mars), a zone of minute bodies called asteroids, a group of four large planets (Jupiter, Saturn, Uranus and Neptune) and a series of transient members—the comets and meteors.
25. The theory most generally accepted is that the gradual shrinkage of the matter composing the body of the sun accounts for the maintenance of its heat. This theory is due to Helmholtz.

26. Different parts of the sun have different rates of rotation, the polar regions taking a longer time for a complete revolution than do the equatorial parts. Thus the sun does not rotate like a solid body.

27. Only the inner planets, Mercury and Venus, pass through all the phases. Mars sometimes attains the gibbous phase.

28. Mercury and Venus are supposed to always present the same face to the sun.

29. It is equal to 165 of our years.

30. They are undoubtedly composed of thousands of small satellites.

31. The tail consists of matter expelled from the comet by some force proceeding from the sun.

32. The best available data give about 18,000° Fahrenheit. A temperature of more than 3,000° can be produced at the focus of a burning glass.

33. To determine the presence of iron in the sun, its spectrum is compared with that given out by iron heated to a white heat.

34. The solar corona, which is invisible except during a total eclipse of the sun.

35. The orbit of each planet is an ellipse, the sun being at one focus. The line drawn from the sun to the planet passes over equal areas in equal intervals of time.

36. The actual distance is about 93,000,000 miles. If we allow a speed of 50 miles an hour for the express train the time consumed would be over 200 years.

37. Mercury is over twelve times as dense as water, while Saturn is lighter than water.

38. The strength of gravitation depends upon the mass and diameter of the planet. On account of the greater mass of Jupiter, a man weighing 150 pounds here would weigh 390 pounds there.

39. Mercury. On one portion of its surface the sun always shines; on the opposite portion never. Moreover, it is nearer the sun than any other planet and hence receives more heat.

40. The planet Mars has such a satellite, Phobos.

41. Mars. These caps grow in the Martian winter and shrink, and sometimes disappear in summer.

42. This is due to sunlight reflected from the earth, the so-called "earth shine."

43. Easter is the first Sunday which follows the full moon occurring after March 21. Hence it cannot occur earlier than March 22. If full moon comes on March

21 and that day is Sunday, the next full moon will come twenty-nine and one-half days later, or on April 19, and Easter will be on April 25, the latest possible date.

44. Because it is moving about the earth from west to east.

45. When the earth passes between the sun and the moon it shuts off the sunlight from the moon. This we call an eclipse of the moon.

46. According to this theory the friction of the tides tends to lengthen both the day and the month, but the day more rapidly. At some time in the future the month and day will be equal in length, according to this theory, each being fifty-seven times as long as our present day.

47. The light year, or the distance that light travels in a year. The velocity of light is 186,400 miles a second. It comes from the moon in a second and a quarter, from the sun in eight minutes and thirteen seconds, but from the nearest star it takes over four years.

48. A constellation is one of the areas into which the sky has been divided by arbitrary lines. The number at present recognized is eighty-eight.

49. About four minutes earlier, using standard time. The time in which the earth turns on its axis is really 23 hours 56 minutes of standard time.

50. The sun and moon move steadily eastward, the planets sometimes eastward, sometimes westward.